Instruction Handbook for....

AIL TYPE 137

RF ATTENUATION CALIBRATOR

February 1968

CUTLER-HAMMER

AIRBORNE INSTRUMENTS LABORATORY
DEER PARK, LONG ISLAND, NEW YORK 11729

CONTROL AIL DIVISION

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SECTION I
INTRODUCTION

The AIL Type 137 RF Attenuation Calibrator uses the well-known IF series substitution method for the accurate measurement of attenuation at radio frequencies (Figure 1-1). Using newly developed techniques, it has a single step measurement capability of from 0.01 to 100 dB over the frequency range from 10 MHz to 40 GHz. The AIL Type 137 features operational simplicity, integral automatic frequency control, solid-state design, internal modular construction, and a plug-in mixer capability; it is ideally suited for the calibration laboratory as well as production line use. The AIL Type 137 can also be used for sensitive null measurements, amplitude modulation measurements, noise figure measurements, and frequency deviation measurements. Some of its many uses are:

1. Calibration of RF and IF attenuators and directional couplers,
2. Calibration of signal-generator output attenuators,
3. Measurement of gain, selectivity, and linearity characteristics of RF and IF amplifiers,

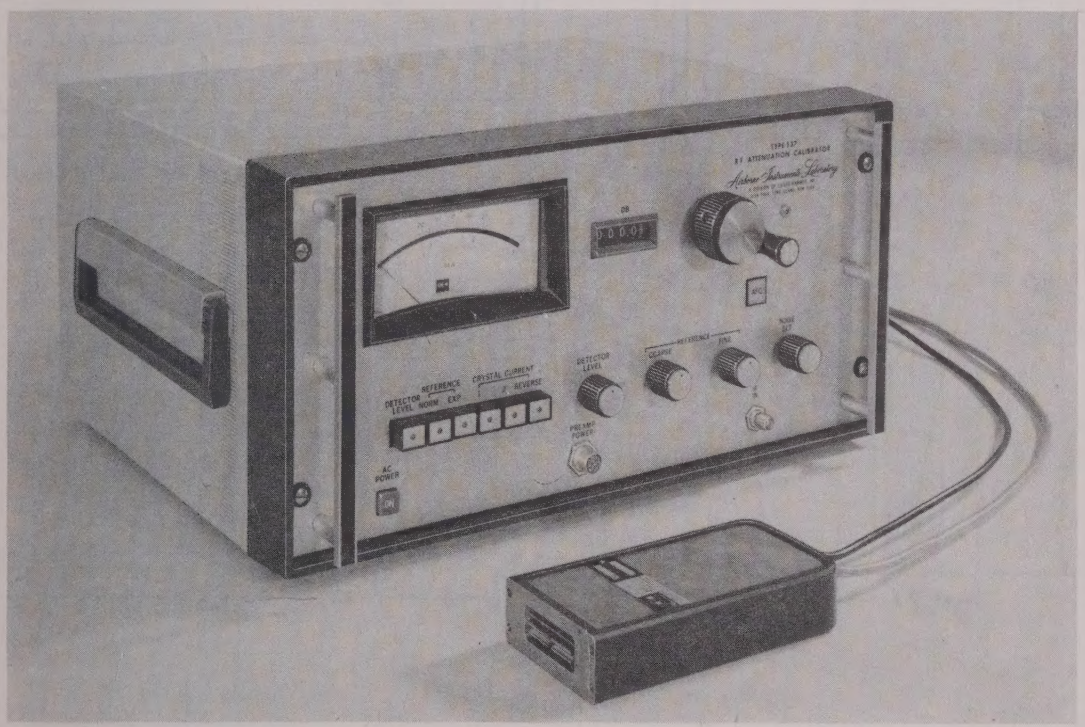


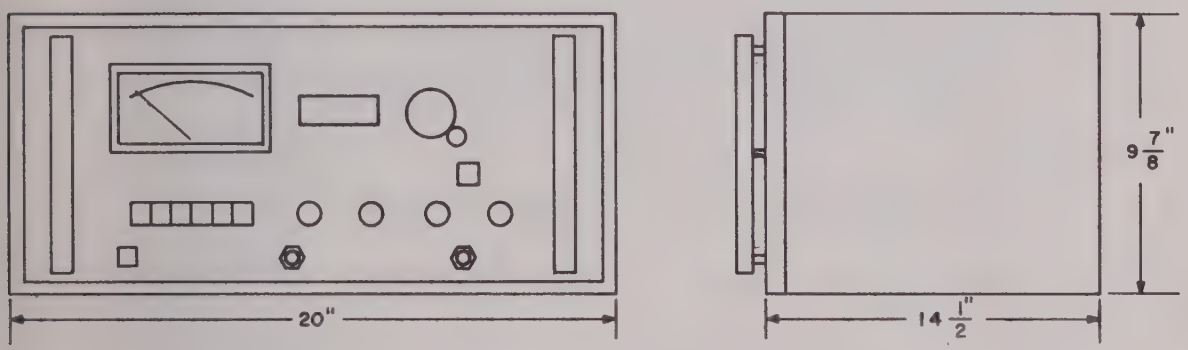
FIGURE 1-1. AIL TYPE 137 RF ATTENUATION CALIBRATOR, P/N 13710

4. Measurement of transmission and selectivity characteristics of RF and IF components (isolators, tuners, power dividers, etc.),
5. Measurement of noise figure of mixers and amplifiers,
6. Measurement of contact losses and hysteresis in RF and microwave switches.

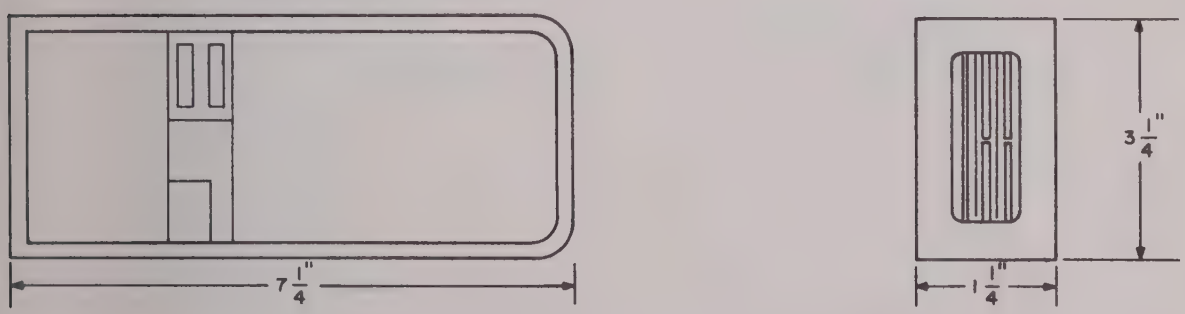
The Type 137 RF Attenuation Calibrator (Figure 1-1) consists of a main unit (Part Number 13710) and a preamplifier-converter (Part Number 13730).

SECTION II
SPECIFICATIONS

1.	Size P/N 13710 (Figure 2-1) P/N 13730 (Figure 2-1)	20 x 9-7/8 x 14-1/2; front panel 8-3/4 x 19 7-1/4 x 3-1/4 x 1-1/4
	Weight P/N 13710 P/N 13730	30 pounds 2 pounds
2.	Frequency range	10 MHz to 40 GHz (determined by mixer, see Appendix A)
3.	RF attenuation measurement accuracy	100.00 dB maximum 0.01 dB minimum



A. 13710



B. 13730

FIGURE 2-1. AIL TYPE 137 RF ATTENUATION CALIBRATOR AND PREAMPLIFIER P/N 13730 OUTLINE DIMENSIONS

4. RF attenuation measurement accuracy

Attenuation Step (dB)	Measurement Accuracy (dB)
10	±0.04
20	±0.05
40	±0.07
80	±0.20
90	±0.30
100	±0.40

5. Signal sensitivity

RF (mixer input)	-115 dBm
IF (30-MHz receiver input)	-125 dBm

6. Automatic frequency control

Frequency drift correction	1000:1 min (Note 1)
Frequency drift range	±5 MHz
Minimum RF signal level	-115 dBm (into mixer)
Frequency lock-on	Green indicator light

7. Discriminator output

AFC FAST (scope presentation)	200 mv/MHz (typical)
AFC SLOW 100 k output impedance)	1000 V/MHz (typical)

8. Output reference indication

Meter	
Resolution, center scale	
Normal	0.2 dB/division
Expand	0.008 dB/division (Note 2)
Recorder output jack	
Output impedance	5.7 k
Output voltage	50.0 mv maximum

Note 1. At signal levels below approximately -90 dBm the correction is less.

Note 2. At signal levels below approximately -90 dBm the normal scale is recommended.

9. Precision attenuator

Center frequency	30 MHz
Minimum insertion loss	18 dB (nominal)
Input impedance (nominal)	50 ohms
Output impedance (nominal)	50 ohms
Attenuation range	0.00 to 100.00 dB above minimum insertion loss
Accuracy	0.005 dB/10 dB + 0.03 dB
Resolution	0.01 dB/division

10. Power required — 115/230 VAC ±10 percent, 50 to 60 Hz, 40 watts

SECTION III

OPERATING CONTROLS AND INDICATORS

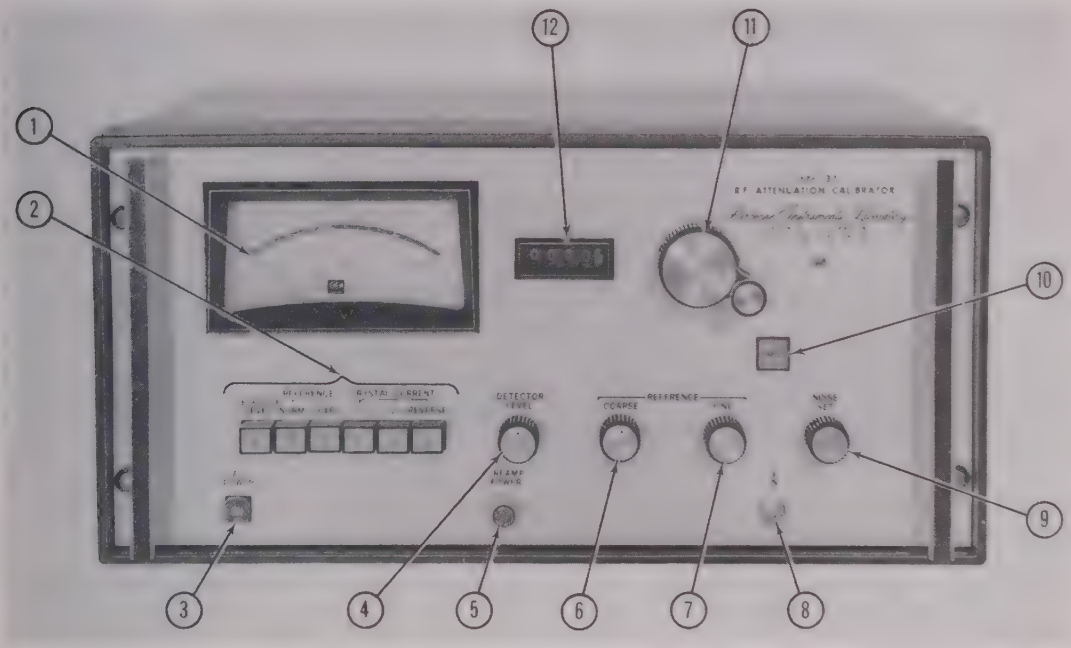


FIGURE 3-1. TYPE 137 FRONT PANEL CONTROLS, INDICATORS, AND CONNECTORS

Reference Number	Control/Indicator	Function
1	Meter	Indicates second detector level, output reference level, or crystal current as selected by switch 2.
2	Meter function switch, six position	Selects meter function.
	DETECTOR LEVEL	Shows IF postamplifier detector current.
	REFERENCE NORM	Shows output level with normal sensitivity.
	REFERENCE EXP	Shows output level with increased sensitivity.
	CRYSTAL CURRENT 1	Shows diode current in RF crystal 1.
	CRYSTAL CURRENT 2	Shows diode current in RF crystal 2.
	CRYSTAL REVERSE	Reverse meter connections when monitoring crystal current.

Reference Number	Control/Indicator	Function
3	AC POWER indicator-switch	Controls AC input power. Illuminates when power is on.
4	DETECTOR LEVEL control	IF postamplifier gain control used to set detector signal level.
5	PREAMP POWER connector	Used to supply power to the preamplifier-converter, control voltage for the VCO, and provide a connection for monitoring crystal current.
6	REFERENCE COARSE control	Used with REFERENCE NORM or EXP to make coarse setting of reference level.
7	REFERENCE FINE control	Used with REFERENCE NORM or EXP to make fine setting of reference level.
8	IF IN connector	Provides access to the input of the 30 MHz preamplifier.
9	NOISE SET control	Used to adjust the output of the internal noise generator. Used with REFERENCE NORM only.
10	AFC indicator	Indicates when AFC is locked to a signal. Also when no signal is present, it indicates large noise unbalance.
11	Precision attenuator control	Used to adjust the setting of the precision attenuator.
12	DB indicator	Relative attenuation in dB.

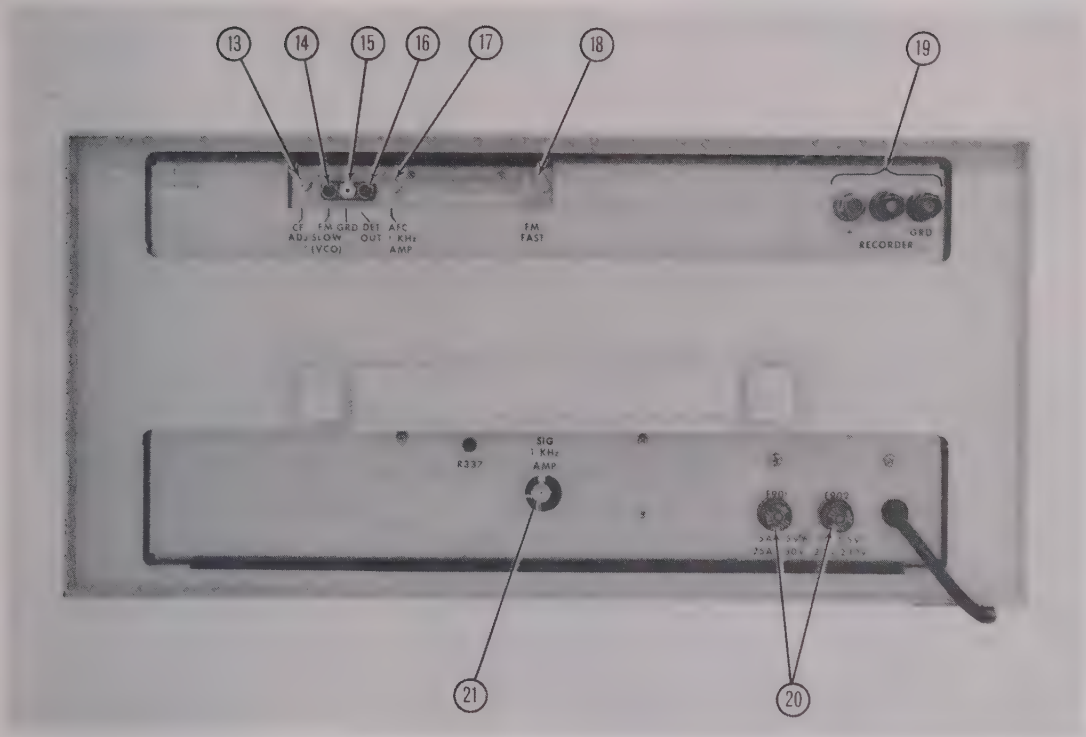


FIGURE 3-2. TYPE 137 RF ATTENUATION CALIBRATOR, REAR VIEW

Reference Number	Control/Indicator	Function
13	CF ADJ	Calibration adjustment for setting the VCO center frequency.
14	FM SLOW, VCO	Monitor point for AFC output voltage used to control internal VCO and monitor slow frequency deviations.
15	GND	Provide ground connection.
16	DET OUT connector	Used to monitor the output of the AFC coherent detector.
17	AFC 1KHZ AMP connector	Used for maintenance purposes to monitor the audio signal at the input to the coherent detector in the AFC channel.
18	FM FAST	Monitor point for discriminator output used to measure incidental frequency deviation of the signal sources.

Reference Number	Control/Indicator	Function
19	RECORDER terminals	The (+) and (-) terminals provide direction connection to the front panel meter through a 4.7 k resistor. The + terminal is grounded by a switch.
20	F901, F902	Fuse holders for input line fuse.
21	SIG 1KHZ AMP connector	Used for maintenance purposes to monitor the audio signal at the input to the coherent detector in the signal channel.

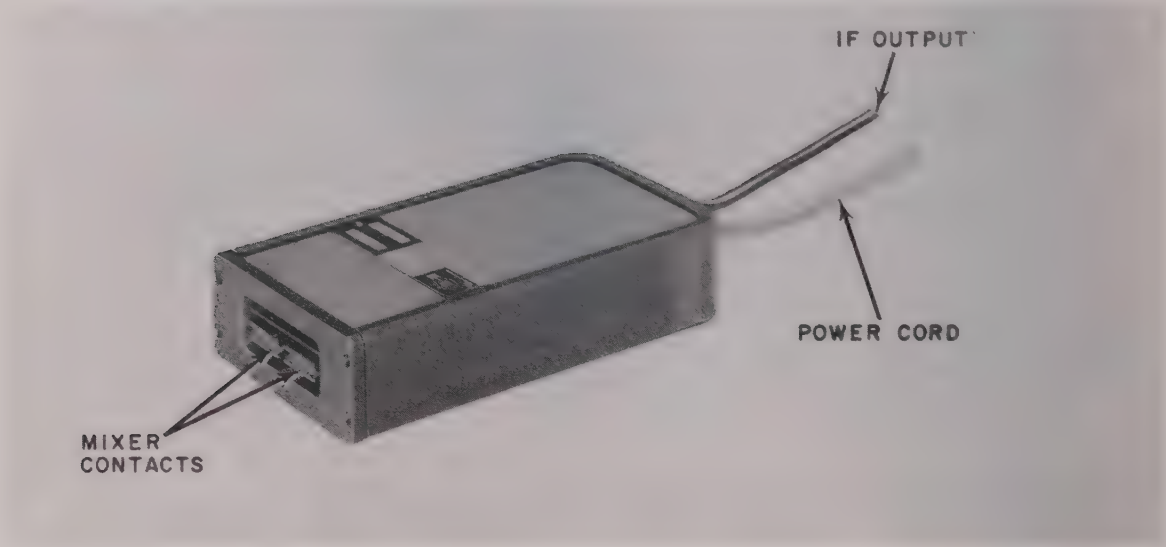


FIGURE 3-3. PREAMPLIFIER CONVERTER CONNECTORS

22	IF output	IF output to front panel.
23	Power cable	Connects power to preamplifier.
24	Mixer contacts	Provides contacts to mixer output.

SECTION IV
OPERATING INSTRUCTIONS

4-1 INTRODUCTION

The Type 137 RF Attenuation Calibrator may be used to perform measurements of RF attenuation, IF attenuation, frequency deviation, amplitude modulation, and noise figure. It may also be used as a highly sensitive null indicator in bridge and switched-type comparison systems.

This instrument is based on the series IF substitution principle. In this system two attenuators, an unknown and variable IF standard, are placed in series between a generator and a detector (Figure 4-1). Essentially, the measurement method consists of keeping the sum of the attenuation of the unknown and the standard at a constant value. The measurement of RF attenuation using the IF substitution method requires the use of a mixer to convert the frequency of the input signal to the 70 MHz center frequency of the first IF preamplifier located in the converter. AIL offers mixers (Appendix A) which can be conveniently mated to the 70 MHz preamplifier and which cover the frequency range of 10 MHz to 40 GHz.

FIGURE 4-1. TYPICAL TEST SETUP

The local oscillators which are needed for obtaining the frequency conversion can be standard commercially available signal sources such as the AIL Type 125 (Appendix A). The AIL Type 137 system has been designed so that it is not necessary to amplitude modulate or electronically control the frequency of the signal sources. Since these functions are not necessary, less sophisticated signal sources and generators may be used.

4-2 RF ATTENUATION MEASUREMENTS

The arrangement of the basic test equipment required for RF attenuation is shown in Figure 4-2. In this system, the mixer converts the change of the RF power level to an equal, linearly related, power level change at the 70 MHz IF. The front panel meter or a recorder may be used to monitor a change in the IF signal level. A precision, highly accurate, waveguide-below-cutoff, IF attenuator, located in the receiver, should be adjusted so that the meter or recorder indicator is at the same position for two conditions; (1) the IF standard is at a 0.00 dB (reference) setting and the unknown RF attenuator is in the system, and (2) the unknown is removed and the system reconnected. There are three major factors that limit the measurement range and accuracy of an IF-substitution system: the nonlinearity of the mixer at high RF signal levels, the effects of the presence of noise at low RF signal levels, and amplitude instability of the IF signal due to frequency variations of the RF signal and local oscillator. In the Type 137, a new noise stabilization technique overcomes the effects of the background noise and a coherent frequency control loop reduces errors caused by frequency variations of the RF signal and local oscillators.

Since the power conversion linearity of the mixer is of prime importance, it is necessary to take certain precautions to assure that deviations from linearity are minimal. The signal level incident on the mixer must be substantially less than the local oscillator level. For linearity deviations to be less than 0.01 and 0.10 dB, the signal power should be 21 and 15 dB, respective, below the local oscillator power. The AIL Type 135 mixers require approximately 2 mw of local oscillator power (1.0 ma of crystal current) to ensure optimum noise matching and conversion efficiency. Therefore, when performing single-step RF attenuation measurements of less than 80 dB, the signal power should be set for approximately -20 dBm and the local oscillator power should be set for approximately +3 dBm. When attenuators are inserted into the system to improve the VSWR of the mixer, the power levels should be increased accordingly. The operator should perform a run of measurements using a "boot strap" technique to obtain a linearity curve for the mixer he uses.

Good RF attenuation measurement techniques and practices require that certain precautions be observed in order to eliminate or minimize system measurement errors. In the measurement process some of the errors will be random and their effect can be reduced by averaging the results of a number of measurements. An example of a random error is the operator's inability to reset the position of the meter pointer exactly to the reference position after removing the unknown RF attenuator.

Techniques for reducing measurement errors due to mismatch, signal source instability, RF leakage, and alignment variations are discussed in Appendix B (Techniques of Attenuation Measurement).

The basic measurement setup is shown in Figure 4-2. A more sophisticated setup utilizing pads, isolators, directional couplers, tuners, etc. is shown and discussed in Appendix B. The measurement procedure is as follows.

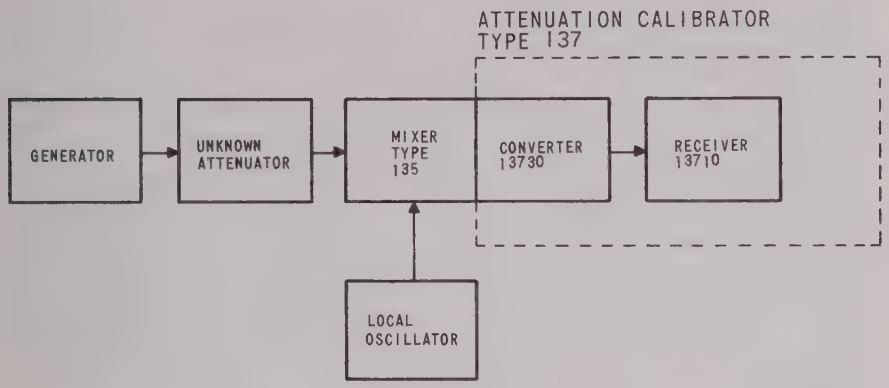


FIGURE 4-2. BASIC RF ATTENUATION MEASUREMENT EQUIPMENT

4-3 INITIAL TURN-ON PROCEDURES

a. Connect converter power cable to PREAMP POWER connector of receiver.

b. Connect IF coaxial cable of converter to IF IN connector on receiver.

c. Depress AC POWER indicator-switch, the indicator and front meter panel will light. A 1/2 hour "warm up time" is recommended prior to taking precision measurements.

d. Rotate precision IF attenuator until a reference reading of 0.00 dB is observed.

NOTE

To eliminate any errors caused by backlash in the attenuator, 0.02 dB, always rotate the attenuator in the same direction when obtaining the reference and final settings. It is recommended that the attenuator be rotated in a counterclockwise (CCW) direction.

4-4 CRYSTAL CURRENT ADJUST

a. Set RF local oscillator frequency to approximately 70 MHz higher or lower than the desired operating frequency.

b. Adjust local oscillator output power for approximately 0 dBm, CW operation.

c. Depress CRYSTAL CURRENT 1 switch and observe meter reading on the 3 ma scale. If meter reads offscale (to the left), depress REVERSE switch. The crystal current reading should be approximately 1.5 ma. It may be necessary to readjust the local oscillator power level. To

ensure proper mixer operation depress the CRYSTAL CURRENT 2 switch. The crystal current reading should be approximately the same as crystal current 1.

4-5 RF SIGNAL GENERATOR ADJUSTMENTS

a. Depress DETECTOR LEVEL switch and rotate DETECTOR LEVEL control to an extreme CCW position. This corresponds to a minimum IF gain adjustment. Set the REFERENCE COARSE control to approximately 3/4 of an extreme CW position.

b. Set the RF signal generator to the desired operating frequency, CW output.

c. Adjust the signal generator output power for approximately -20 dBm at the mixer input. When it is difficult to measure or determine the power level the following techniques may be used. Turn off the local oscillator power and adjust the signal generator output power for approximately 1 ma of crystal current. This will correspond to approximately +3 dBm signal power. Insert a total of 23 dB of attenuation between the generator and mixer; there will be approximately -20 dBm signal power incident on the mixer. Turn on the local oscillator power and reset to the proper level as described previously.

4-6 AUTOMATIC FREQUENCY LOCK

When the frequency difference between the local oscillator and the signal generator is within the capture range of the AFC loop, the green AFC indicator will illuminate.

a. Slowly vary the frequency of the local oscillator until the AFC indicator is illuminated. The system will then be in automatic frequency control. During this procedure, depress DETECTOR LEVEL switch and observe a peak on the meter. Since the response time of the meter is faster than that of the AFC indicator, it is an added convenience to use the meter during the tuning procedure.

b. In many instances it is desirable during a measurement to know the frequency stability of the RF signal and local oscillators. This can be done conveniently by connecting a DC voltmeter to "AFC SLOW" jack on the rear of the receiver. The frequency drift can be measured according to the instructions in paragraph 4-27.

4-7 NOISE SET ADJUSTMENT

When making single step RF attenuation measurements of greater than 40 dB, it is desirable to stabilize the system noise for maximum accuracy. Also, as a standard procedure, it is recommended that the noise set be adjusted when a new mixer is initially connected to the preamplifier-converter unit.

a. Connect the unknown RF attenuator into the system as shown in Figure 4-2.

b. Set the IF precision attenuator at 0.00 dB using CCW rotation.

c. Turn off the RF signal generator.

d. Depress the DETECTOR LEVEL switch and rotate the DETECTOR LEVEL control until the meter indicator lies in the marked area, DET LEV.

e. Depress REFERENCE NORM switch and adjust the NOISE SET control until the meter indicator is on NOISE SET. To obtain a finer null, increase the gain by adjusting REFERENCE COARSE control in a CW direction.

NOTE

The noise level adjustment which has been performed will only be valid for a measurement in which the precision IF attenuator is set to an initial reference setting of 0.00 dB. However, this adjustment is independent of changes in the DETECTOR LEVEL or REFERENCE control position.

4-8 REFERENCE INDICATION

The series IF substitution method is based upon obtaining the same reference indication when the unknown RF attenuator is both in and out of the system.

a. With the unknown RF attenuator in the system, turn on the RF signal generator and obtain frequency lock. It may be necessary to readjust the local oscillator frequency.

b. Depress the DETECTOR LEVEL switch and adjust the DETECTOR LEVEL control until the meter indicator lies in the area marked DET LEV.

c. Depress REFERENCE NORM switch and adjust the REFERENCE COARSE control until the meter indicator lies approximately at mid-scale. The resolution of the meter indicator at this setting is approximately 0.10 dB for each division. To increase the resolution, depress REFERENCE EXP switch and adjust the REFERENCE FINE control to obtain a meter indication. The resolution in EXP is approximately 0.008 dB for each division. Note the position of the meter indicator.

d. Remove the unknown attenuator and rotate the IF precision attenuator until the same reference indication is returned as in step c.

e. Read the attenuation in dB directly off the digital indicator. The smallest subdivision on indicator is equivalent to 0.01 dB.

4-9 REFINEMENTS IN OPERATING TECHNIQUES

After mastering the basic measurement procedure, the operator will be able to improve the facility of measurement through attention to the following refinements in operating techniques.

4-10 AIL Type 135 Balanced Mixers

The method for monitoring crystal current in the AIL Type 135 balanced mixers was described in paragraph 4-4. In most cases, the current flowing through either crystal will be within 20 percent of each other. However, due to aging or damage, a crystal may become defective and the current will be badly unbalanced. It is recommended that if the current unbalance is greater than 50 percent, the diodes should be checked and the faulty unit replaced. The diodes may be checked with the AIL Type 391 Crystal Checker (Appendix A) or an equivalent instrument.

4-11 Crystal Current

When placing the system into automatic frequency control, the local oscillator frequency should be varied until the signal is "captured." Characteristic of any sources, the power output level will change as the frequency is varied; therefore, after the loop is in automatic frequency control, the crystal current should be rechecked.

4-12 RF Signal and Local Oscillator Power Level Instabilities

During a measurement, an error will occur if the local oscillator or signal power levels should vary. The error will be a one-to-one relationship for a change in the level of the signal power. However, the error will be approximately a one-to-eight relationship for a change in the level of the local oscillator power. Therefore, in setting up a measurement system, the least stable RF source should be used, if possible, as the local oscillator.

4-13 Output Meter Scales

When single-step RF attenuation measurements of up to approximately 75 dB are performed, the expanded output scale, REFERENCE EXP, should be used. For attenuation measurement steps of greater than 80 dB, the normal scale, REFERENCE NORM, should be used. When making a single-step measurement of 80 dB or greater, the signal level at the converter input will be approximately -90 dBm or lower. At these low levels, the signal-to-noise ratio is poor and fluctuations in meter indication will occur. On the expand scale, where the sensitivity is 0.008 dB for each division, these fluctuations will be difficult to average visually. However, on the normal scale (0.1 dB division) the fluctuations will be smaller and the average position of the indicator setting may actually be more accurately determined. The measurement range at which the operator would use the REFERENCE NORM range rather than EXP is a matter of personal preference and varies with the degree of accuracy required.

4-14 Automatic Time Constant Control

When a single-step attenuation measurements of greater than 75 dB are performed, there will be meter needle fluctuations due to the presence of noise voltages. The method utilized in the Type 137 to reduce these fluctuations is to increase the meter time constant and therefore decrease the effective bandwidth. To relieve the operator from calculations or experimentation to determine the required time constant, an automatic time constant control is featured in the unit. As the REFERENCE COARSE control is rotated clockwise (increased gain) the time constant increases automatically. The meter response will be much slower at low signal levels than at higher signal levels; therefore, when making a measurement, it is advisable to adjust the IF attenuator to its approximate final setting, then wait a few seconds, and then slowly rotate the attenuator control counterclockwise until the reference indication is obtained on the meter.

4-15 Noise Set

It is necessary to adjust the NOISE SET control to obtain accurate single-step RF attenuation measurements of greater than approximately 40 dB. When the REFERENCE COARSE control is rotated in a CW direction the NOISE SET control increases in sensitivity. At the high sensitivity settings of the control the need for setting the meter needle to the noise set marker on the meter face is important. When there is no RF input signal (refer to Noise Set procedure), the AFC light also functions as a coarse indicator of a poor setting of the NOISE SET. When the NOISE SET control is misadjusted, the AFC indicator will be illuminated.

4-16 Recorder Reference Indication

In some cases it will be desirable to have a record of the reference indication at the initial and final settings of the IF attenuator. RECORDER terminals are provided at the rear of the unit for this purpose. This has the advantage of using a mechanical memory element rather than the operator's memory for returning to the reference indication. An additional advantage of a recorder output is that the operator can more accurately integrate any fluctuations of the reference indication.

Since the RECORDER output terminals are directly connected to the meter through a 4.75 resistor, it is very convenient to monitor crystal current to determine if any change occurs in the power level of the local oscillator. CRYSTAL CURRENT 1 or 2 switches should be depressed for this measurement.

4-17 Spurious Frequency Responses

In the Type 137 RF Attenuation Calibrator, the RF signal is converted to 30 MHz by double frequency conversion. The first conversion is in the RF mixer, the second is in a wide-band mixer having a nominal 100 MHz Voltage-Controlled Local Oscillator (VCLO) input.

For a fixed RF local oscillator frequency, f_{LO}, the spectrum of the two acceptable RF responses and the principal spurious responses are shown in Figure 4-3. A narrowband, 60 to 80 MHz, bandpass filter positioned between the RF and wide-band mixers reduces the spurious responses to a level at least 50 dB below the main response. Furthermore, the AFC loop would not "lock on" to a 130 MHz response because the loop would be 180 degrees out of phase and it would attempt to "push away" rather than capture the signal.

To ensure the loop does not lock on to a minor spurious response, especially when the receiver gain is set to a maximum and the RF signal level is very high, the DETECTOR LEVEL switch position should be used when tuning the external local oscillator. The largest meter deflection will only occur when the RF and local oscillator frequencies are properly set for the desired response.

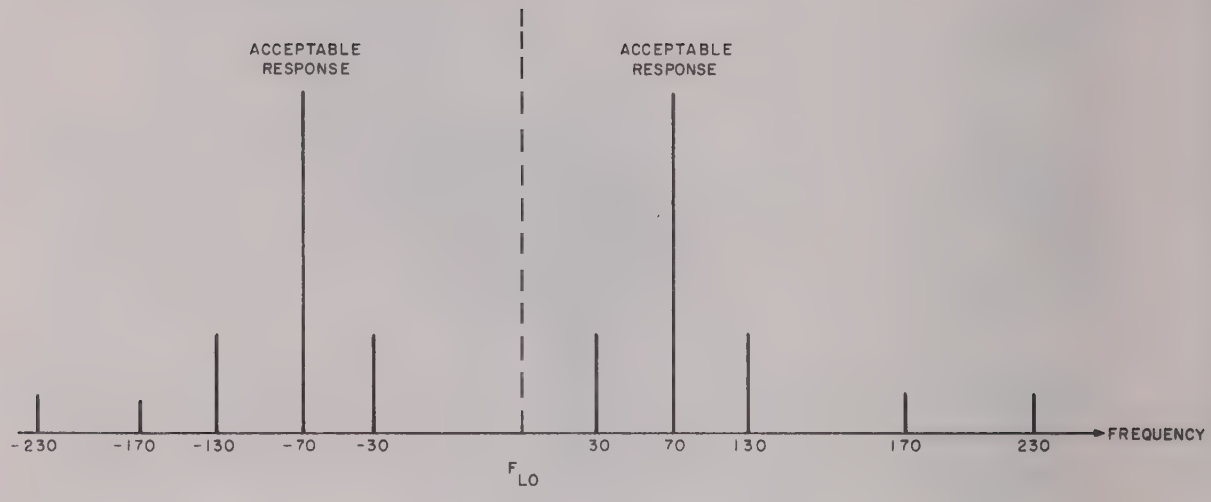


FIGURE 4-3. FREQUENCY RESPONSE SPECTURM

4-18 AFC Indication

When the heterodyned signal is within the capture range of the VCO, the AFC loop will "lock on." However, this is conditional upon the IF signal level being of sufficient magnitude. When the meter needle lies in the recommended area, DET LEV, there is sufficient signal level to lock the AFC loop. In fact, approximately 10 to 20 dB below this level the loop will still lock but with degraded capture and hold-in range performance.

An indication of AFC lock is provided by an illumination of the AFC light. The audio signal which is fed to the third detector is also used to control the on-off state of the light. When the meter deflection in the REFERENCE NORM position is greater than the minimum scale marking of -25, the audio signal is of sufficient magnitude to turn on the light. When the REFERENCE controls are adjusted so that the indicator lies to the left of the -25 scale mark, the AFC light may go out even if the AFC loop is locked.

Another means for determining that the loop is locked is to connect a high impedance DC voltmeter to the AFC SLOW jack at the rear of the receiver. This voltage controls the VCO frequency and will vary as the nominal 70 MHz IF frequency is varied. Therefore, slowly change the frequency of the RF local oscillator and observe the tracking of the VCO by noting a change in the control voltage (approximately one half volt for each megacycle change).

4-19 VCO Correction Voltage

The capture range for the AFC loop at high signal levels is approximately 3 MHz. The VCO "resting" or "no lock" voltage (available at the test terminal, AFC SLOW) is nominally 10 volts, which corresponds to a 100 MHz VCO frequency. This means that in order to lock the loop, the frequency difference between the RF signal source and local oscillator must be 70 MHz $\pm$1.5 MHz. However, depending upon the IF gain and noise balance settings this nominal VCO voltage can vary by a few volts. Therefore, when the loop is locked, it is desirable to have the VCO voltage read the same as when no input signal is present. When this condition is satisified the AFC circuit is operating near the center of its range, the 70 MHz signal is located near the center of the pass band of the 70 MHz amplifier, and as a result maximum stability of the AFC system is obtained.

4-20 AFC Lock at Low Signal Levels

The capture range of the AFC loop will remain constant at high signal levels. However, at low signal levels where poor S/N ratios exist, the AFC loop will have a smaller capture and hold-in range. At low signal levels, it is possible that the incidental FM of the RF signal source and the local oscillator will cause difficulty in obtaining a lock-in action. For these cases, the loop may be more easily locked by first increasing the RF signal level and then decreasing it to the proper level. The usefulness of this technique lies in the fact that the hold-in range of the loop is much greater than its capture range.

4-21 Attenuation Measurements in the Frequency Range of 10 to 1000 GHz

The AFC capability in the Type 137 system minimizes the effect of frequency drift associated with the RF signal and local oscillators. At low frequencies, i.e., below 1000 MHz, the stability of most sources will be satisfactory for performing very accurate attenuation measurements without the need for automatic frequency control. Therefore, it is recommended that our broadband 10 to 1000 MHz mixer, Part Number 13508, be connected directly to the IF input connector on the front panel. A TNC connector is provided with the mixer.

The measurement procedure is modified slightly in that the difference frequency between the signal and local oscillators should be 30 MHz instead of 70 MHz. When a 30-MHz signal is obtained the AFC indicator will be illuminated.

4-22 IF ATTENUATION MEASUREMENTS

The basic IF measurement setup is shown in Figure 4-1. In this system the linear system components should include a fixed attenuator to provide isolation and impedance matching between the unknown and standard attenuators.

A major factor which limits the measurement range and accuracy of the IF-substitution system is the effects of the presence of noise at low signal levels. The presence of noise degrades the resolution and causes an uncertainty in the position of the reference indicator. In the Type 137 system, a coherent amplitude detector improves the resolution and minimizes the uncertainty of the reference indicator position.

Good IF attenuation measurement techniques and practices should be observed in order to eliminate or minimize system measurement errors. The techniques and practices are similar to those required in RF attenuation measurements. Therefore, it is recommended that the operator refer to the appendix entitled "Techniques of Attenuation Measurement."

The basic measurement setup is shown in Figure 4-1. The measurement procedure for a 30-MHz attenuation measurement is as follows.

4-23 INITIAL TURN-ON PROCEDURES

For this measurement the preamplifier-converter Part Number 13730 is not required.

a. Depress AC POWER indicator-switch, the indicator and front panel meter will light. A half-hour warmup time is recommended prior to taking precision measurements.

b. Rotate precision IF attenuator until a reference rating of 0.00 dB is observed.

NOTE

To eliminate any errors caused by backlash in the attenuator, typically 0.02 dB, always rotate the attenuator in the same direction when obtaining the reference and final settings. It is recommended that the attenuator be rotated in a counterclockwise (CCW) direction.

4-24 IF SIGNAL GENERATOR ADJUSTMENTS

a. Set IF signal generator to 30 MHz, CW operation. Adjust generator output so that when the unknown attenuator is not in the system the signal level at the Type 137 IF input will be -10 dBm. When the generator output is set properly the AFC indicator light will illuminate.

b. Depress DETECTOR LEVEL switch and rotate DETECTOR LEVEL control to an extreme CCW position. This corresponds to a minimum IF gain adjustment. Set REFERENCE COARSE adjust to approximately 3/4 of an extreme CW position.

c. To ensure maximum receiver sensitivity, slowly vary generator frequency until a peak is noted on the meter. To obtain maximum resolution, decrease IF signal level so that meter indicator lies in the area marked DET LEV. Depress the REFERENCE NORM or EXP switch to achieve even greater resolution.

4-25 NOISE SET ADJUSTMENT

When making single-step attenuation measurements of greater than 50 dB, it is desirable to stabilize the system noise for maximum accuracy.

a. Connect unknown IF attenuator into the system as shown in Figure 4-1.

b. Set IF precision attenuator at 0.00 using CCW rotation.

c. Turn off IF signal generator.

d. Depress DETECTOR LEVEL switch and rotate DETECTOR LEVEL control until meter indicator lies in the area marked DET LEV.

e. Depress REFERENCE NORM switch and adjust NOISE SET control until meter indicator is on NOISE SET. To obtain a finer null, increase gain by adjusting REFERENCE COARSE control in a CW direction.

NOTE

The noise level adjustment which has been performed will only be valid for a measurement in which the precision IF attenuator is set to an initial reference setting of 0.00 dB. However, this adjustment is independent of changes in the DETECTOR LEVEL or REFERENCE controls.

4-26 REFERENCE INDICATION

The series IF substitution method is based upon obtaining the same reference indication when the IF attenuator is both in and out of the system.

a. With unknown IF attenuator in the system, turn on IF signal generator, depress DETECTOR LEVEL switch and adjust DETECTOR LEVEL control until the meter indicator lies in the area marked DET LEV.

b. Depress REFERENCE NORM switch and adjust REFERENCE COARSE control until meter indicator lies approximately at midscale. To increase the resolution, depress REFERENCE EXP switch and obtain a meter indication by adjusting REFERENCE FINE control.

c. Note the position of the meter indicator. When a record of the reference indication at the initial and final setting of the IF attenuator is desired then a recorder should be connected to the RECORDER terminals on the back of the receiver.

d. Remove unknown attenuator and rotate the IF precision attenuator until the same reference indication is returned as in step c.

e. Read attenuation in dB directly off digital indicator. The smallest subdivision on the indicator is equivalent to 0.01 dB.

4-27 FREQUENCY DEVIATION MEASUREMENTS

The Type 137 RF Attenuation Calibrator may be used to provide information on the frequency stability of the RF signal source relative to the RF local oscillator.

The basic frequency deviation measurement setup is shown in Figure 4-4. In this system, a frequency discriminator converts the change in the frequency of the second IF signal to a proportional change in voltage. The nominal second intermediate frequency, f_{IF}, is 30 MHz. This frequency is generated in the double, frequency conversion process.

$$f_{IF} = f_{VCO} - \left| f_{RF} - f_{LO} \right| \quad (1)$$

where

f_{RF} = frequency of RF signal,

f_{LO} = frequency of RF local oscillator,

f_{VCO} = frequency of VCO, nominally 100 MHz.

When the solid-state voltage-controlled oscillator is at a much lower frequency than the radio frequency then, in most cases, it is reasonable to assume that it is more stable; therefore,

$$\Delta f_{IF} = \Delta \left(f_{RF} - f_{LO} \right) \quad (2)$$

Thus, the frequency deviation measurement will be a measurement of the stability of one RF source relative to the other.

The accuracy of the measurement is dependent upon knowledge of the voltage-frequency characteristic of the discriminator. To ensure that this characteristic remains relatively constant, it is necessary to provide a signal of sufficient strength for proper limiting action.

When precise knowledge of the voltage-frequency characteristic of the discriminator is required, the following calibration technique may be utilized.

3-28 CALIBRATION OF DISCRIMINATOR CHARACTERISTIC

a. Connect output of a signal generator to IF connector on receiver front panel. The frequency dial on the generator should be calibrated, or a frequency counter should be connected to the generator output.

b. Set generator to 30 MHz and CW mode.

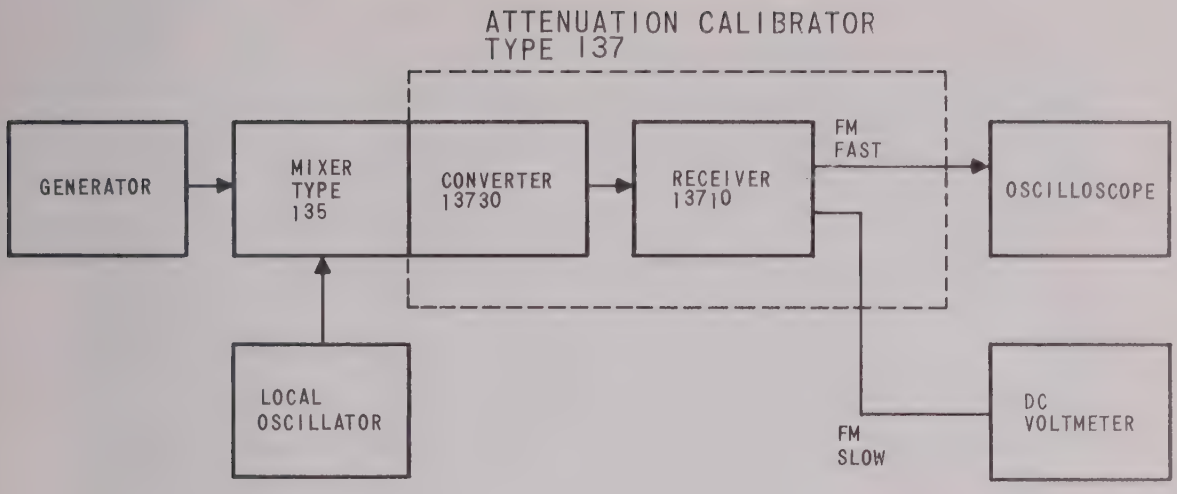


FIGURE 4-4. FREQUENCY DEVIATION MEASUREMENT SETUP

c. Adjust receiver gain to a minimum by turning the DETECTOR LEVEL control fully counterclockwise.

d. Adjust generator output so that receiver indicator lies in marked area DET LEV when DETECTOR LEVEL switch is depressed.

e. Monitor FM SLOW and FM FAST outputs in back of receiver as shown in Figure 4-4.

f. Vary generator frequency and record voltage at the FM SLOW and FM FAST outputs. A voltage-frequency characteristic can then be plotted from the data taken. Figure 4-5 is a plot of data taken from FM FAST output monitor.

g. Slow frequency deviation measurements are generally performed when the AFC loop is locked. Therefore, the FM SLOW frequency-voltage characteristic must be obtained under this condition. The FM FAST characteristic can be measured without the loop being locked. To obtain the FM SLOW frequency-voltage characteristic, vary the VCO control voltage by adjusting control marked CF ADJ and monitor the frequency change of the VCO. A characteristic of MHz/volt will be obtained. It will very nearly be 1.67 MHz/volt.

The procedure for measuring frequency deviation is as follows.

4-29 Initial Turn-On Procedures

a. Connect power cable of preamplifier-converter to the preamp power connector of the receiver. Connect the IF coaxial cable of the converter to the IF IN connector on the receiver.

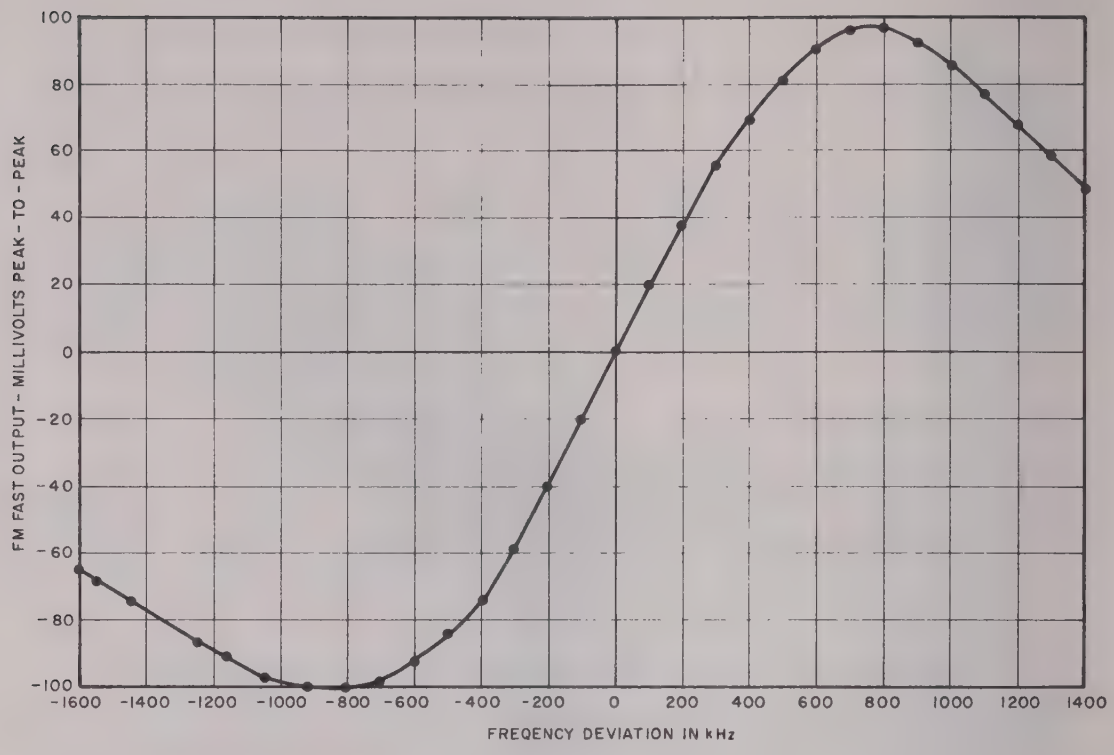


FIGURE 4-5. RATIO DETECTOR OUTPUT

b. Depress the AC POWER indicator-switch, the indicator and front panel meter will light. A one-half hour warmup time is recommended prior to taking precision measurements.

c. Rotate the precision IF attenuator until a reading of 0.00 dB is observed.

4-30 Crystal Current Adjust

a. Set RF local oscillator frequency to approximately 70 MHz higher or lower than the desired operating frequency.

b. Adjust local oscillator power level for a crystal current reading of approximately 1.5 ma.

4-31 RF Signal Generator Adjustments

a. Rotate DETECTOR LEVEL control to an extreme counterclockwise position and depress DETECTOR LE VEL switch. Rotate REFERENCE COARSE control to a 3/4 clockwise position.

b. Set RF signal generator to desired operating frequency, -20 dBm output power, and CW mode.

4-32 AFC Lock

a. Note DC voltage from FM slow monitor jack.

b. Slowly vary frequency of local oscillator until AFC indicator is illuminated. When the loop is locked, slowly vary the local oscillator until the voltage in step a is returned. This ensures that the signal frequency is centered within the discriminator band pass. Thus for incidental FM measurements the entire discriminator bandwidth can be utilized.

c. Check for proper crystal current. Adjust the local oscillator power output if necessary.

d. Adjust signal generator output so that meter indicator lies in the area marked DET LEV.

4-33 Monitor Discriminator Output

a. To measure incidental FM, observe the peak-to-peak voltage excursion at the FM FAST monitor point.

b. The frequency deviation is calculated by using equation 3.

$$\Delta f = K V_{p-p} \tag{3}$$

where

Δf = frequency deviation,

K = slope of discriminator characteristic, 200 mv/MHz,

V_{p-p} = peak-to-peak voltage.

If a more accurate calculation is desired, then the value of K should be determined from the plot obtained in paragraph 4-27. A photograph of the voltage which may typically appear at the FM FAST monitor point is shown in Figure 4-6.

c. To measure slow frequency drift, observe the change in voltage at the FM SLOW monitor point. The value of K for this case is typically 1.67 MHz/volt.

4-34 AMPLITUDE MODULATION MEASUREMENTS

The Type 137 RF Attenuation Calibrator may be used to measure the amplitude modulation on the output of a signal generator. The basic amplitude modulation measurement setup is shown in Figure 4-2. For this measurement it is necessary to connect an oscilloscope to the AM monitor point on the preamplifier-converter. The monitor point is direct coupled to a square-law detector.

The basic method for measuring amplitude modulation is to first measure the detected output (AM monitor point) when no modulation is applied. A DC voltage will be observed. Secondly measure the detected output when modulation is applied. An audio voltage will be observed. If the carrier level does not change when modulation is applied, the percent modulation can be calculated from the observed values of voltage. Referring to Figure 4-7, when observations are made using a square-law detector, the percent modulation is:

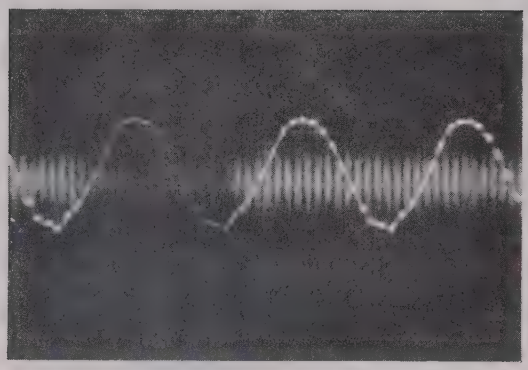


FIGURE 4-6. INCIDENTIAL FM AS DISPLAYED ON OSCILLOSCOPE

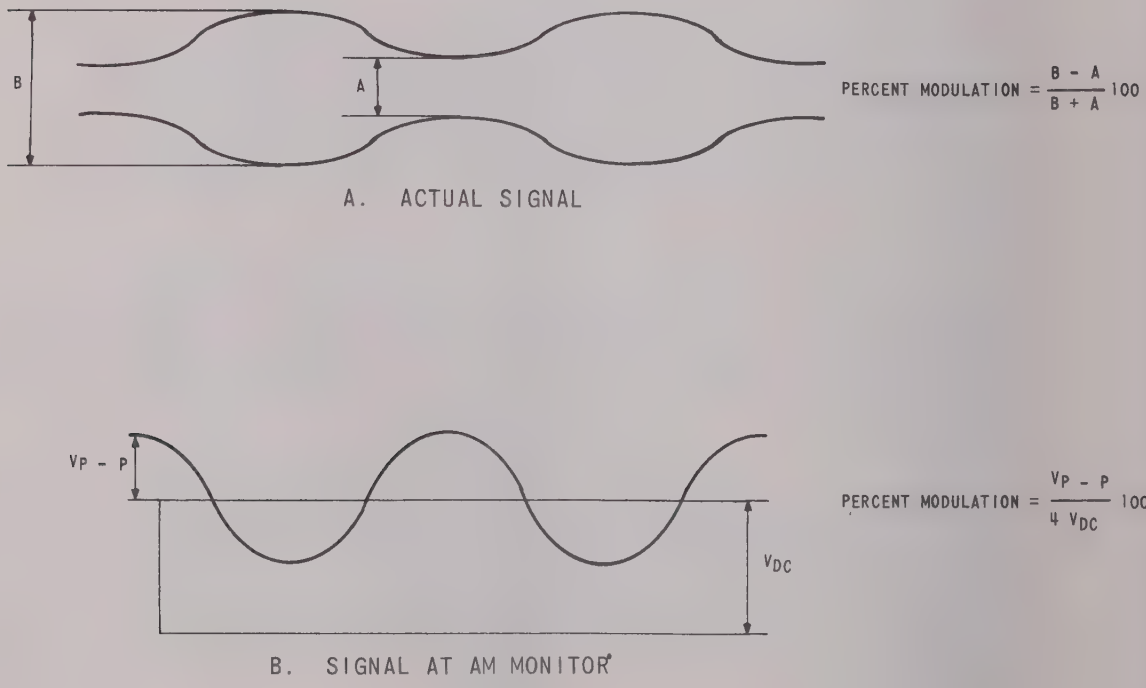


FIGURE 4-7. CALCULATION OF AMPLITUDE MODULATION

$$\text{percent modulation} = \frac{V_{p-p}}{4\ V_{DC}}\ 100 \qquad (4)$$

Figures 4-8 and 4-9 are photographs of oscilloscope displays of the signal and AM monitor output.

The procedure for measuring amplitude modulation is as follows.

Follow the procedure given in paragrapsh 4-29 through 4-32.

Measure the DC voltage at the AM monitor point when no modulation is applied.

Measure the AC voltage when modulation is applied.

Use equation 4 to calculate percent modulation.

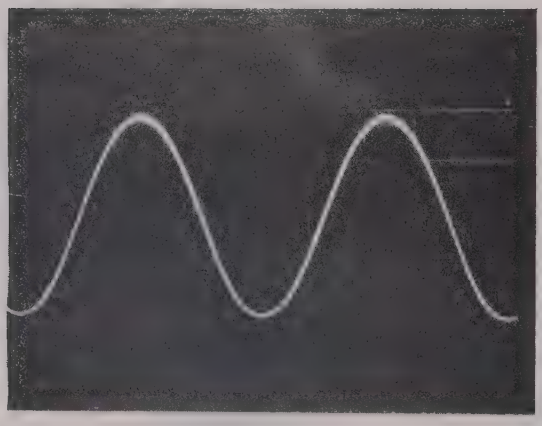
4-35 SENSITIVITY NULL MEASUREMENTS

There are many applications where it is necessary to know the point of adjustment at which a null occurs. In applications involving bridge measurements, dual channel phase measurements, etc., a reference component is generally adjusted to obtain a null condition. In the case of phase measurements, a phase shifter would be adjusted; when a microwave amplifier is being tuned the matching network would be adjusted. In all these cases, the signal would initially be at same high level. The level would then be decreased to a minimum.

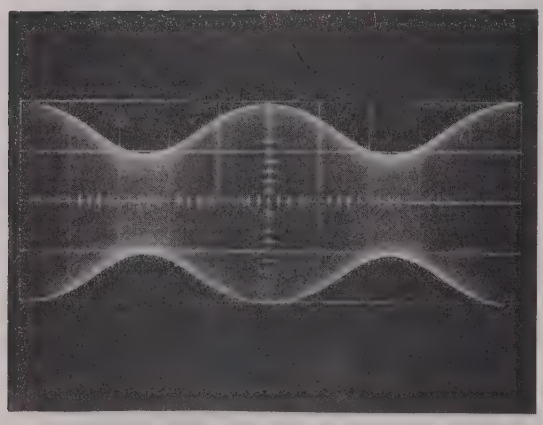
The basic method in performing null measurements is to obtain a reference indication in the same manner as in RF attenuation measurements. However, the signal level in this case will initially be very high. As the null is approached the DETECTOR LEVEL control should be used to keep the detector output near the recommended level (DET LEV). If the approach to the null is relatively slow, the AFC loop will stay in lock. Therefore, the only operating adjustments would be to increase the detector level and reference coarse gain. The initial operating procedures prior to adjusting for a null are similar to paragraphs 4-3 and 4-7. When checking deep nulls approaching the lower limit imposed by system noise, it is necessary to set the precision attenuator at 0.00 dB and follow the normal procedure for adjusting the NOISE set control. It is important to remember that in making null readings the attenuator must not be distributed once the NOISE SET control has been adjusted.

4-36 NOISE FIGURE MEASUREMENTS

The arrangement of the basic test equipment used in making noise figure measurements is shown in Figure 4-10. The noise generator can be any one of a number of devices of known relative excess noise temperature. The most common

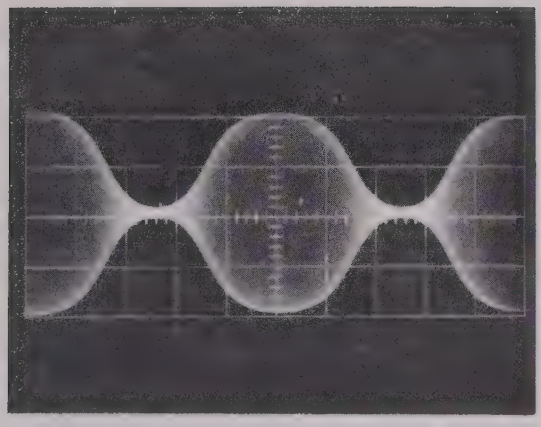


A. IF OUTPUT FROM GENERATOR
PERCENT MODULATION, METER INDICATION - 25
PERCENT MODULATION, CALCULATED - 50

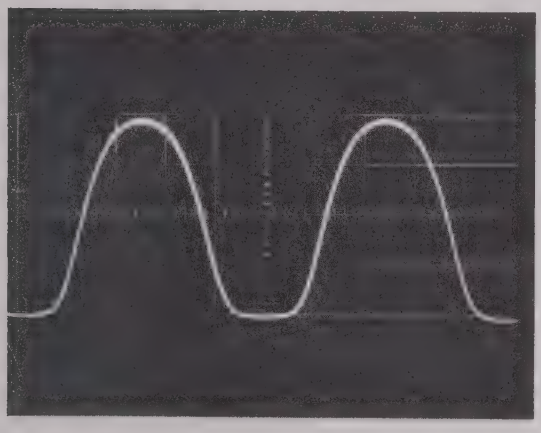


B. DETECTED OUTPUT FROM 137
DC LEVEL - 19 DIVISIONS
AC LEVEL - 20 DIVISIONS
PERCENT MODULATION, CALCULATED - 26

FIGURE 4-8. MODULATION WAVEFORMS, LOW MODULATION



A. IF OUTPUT FROM GENERATOR
PERCENT MODULATION, METER INDICATION - 70
PERCENT MODULATION, CALCULATED - 86



B. DETECTED OUTPUT FROM 137
DC LEVEL - 8 DIVISIONS
AC LEVEL - 20 DIVISIONS
PERCENT MODULATION, CALCULATED - 63

FIGURE 4-9. MODULATION WAVEFORMS, HIGH MODULATION

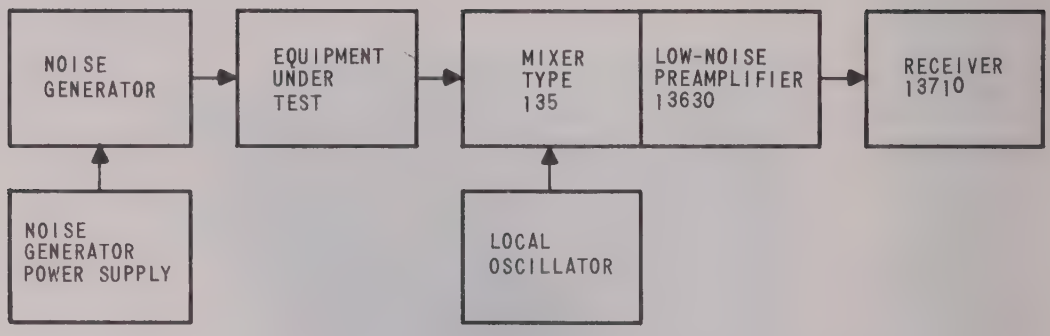


FIGURE 4-10. NOISE FIGURE MEASUREMENT SETUP

are: (1) gas-discharge lamp, where the relative excess noise temperature is primarily a function of the type of gas, the diameter of the discharge column, and the gas pressure; and (2) the thermionic diode, which has a relative excess noise temperature that is a function of the DC diode current and the terminating source resistance.

A Y-factor method is utilized as the basis for the noise figure measurement. When the noise generator is turned off, the input of the device under test sees a passive termination at T_0. The meter indicator position represents a level of noise, N_{01}. When the noise generator is turned on, the meter indicator will increase to a higher position because of the increase of noise at the input. This new position represents a level of noise, N_{02}. If the precision attenuator in the receiver is rotated until the meter indicator position is returned to the same point as when the noise source was off, then this increase is the Y-factor (N_{02}/N_{01}) expressed in dB. This value can then be converted to a power ratio for substitution in equation 5 and the noise figure can be computed.

$$F = \frac{\left(\frac{T_2}{T_0} - 1\right)}{\left(\frac{N_{02}}{N_{01}} - 1\right)} = \frac{T_{EX}}{Y - 1}$$

where

T_2 = temperature of noise generator,

T_0 = temperature of termination.

The basic measurement setup for noise figure measurements is shown in Figure 4-10. The measurement procedure is as follows:

4-37 INITIAL TURN-ON PROCEDURES

a. Connect output of Type 136 low-noise preamplifier to the IF IN connector on receiver front panel; connect power cable of the preamplifier to the PREAMP POWER connector.

b. Depress the AC power indicator-switch; the indicator and front panel meter will light.

c. Rotate the precision IF attenuator until a reference reading of 0.00 dB is received.

4-38 CRYSTAL CURRENT ADJUST

a. Set RF local oscillator frequency to 30 MHz higher or lower than desired operating frequency.

b. Adjust local oscillator output power for approximately 0 dBm, CW operation.

c. Depress CRYSTAL CURRENT 1 switch and observe the meter reading on the 3 ma scale. If meter pegs downscale, depress REVERSE switch. The crystal current reading should be 1.5 ma. It may be necessary to readjust local oscillator power level. To ensure proper mixer operation, depress CRYSTAL CURRENT 2 switch. It should read approximately the same as crystal 1 current.

4-39 RECEIVER GAIN CONTROL ADJUSTMENTS

a. With noise generator turned off, depress the DETECTOR LEVEL switch and adjust DETECTOR LEVEL control so that meter indicator lies in the area marked DET LEV.

b. Depress the REFERENCE COARSE switch and adjust the REFERENCE COARSE control so that the meter indicator is mid-scale position.

c. To achieve finer resolution, depress the REFERENCE FINE switch and adjust REFERENCE FINE control to obtain a reference reading, preferably at mid-scale.

NOTE

The NOISE SET control does not have to be adjusted.

4-40 Y-FACTOR READING

a. Ignite noise lamp by operating noise-generator power supply. Set current adjust control for the proper operating current (refer to the noise-generator handbook).

b. Readjust precision attenuator until meter returns to the reference meter indicator in paragraph 4-39, step c.

c. Read digital dial setting of precision attenuator. This value, in dB, is the Y-factor.

d. Refer to Figure 4-11. Using the T_{ex} curve closest to that given in the noise-generator handbook, read the device noise figure corresponding to the measured Y-factor.

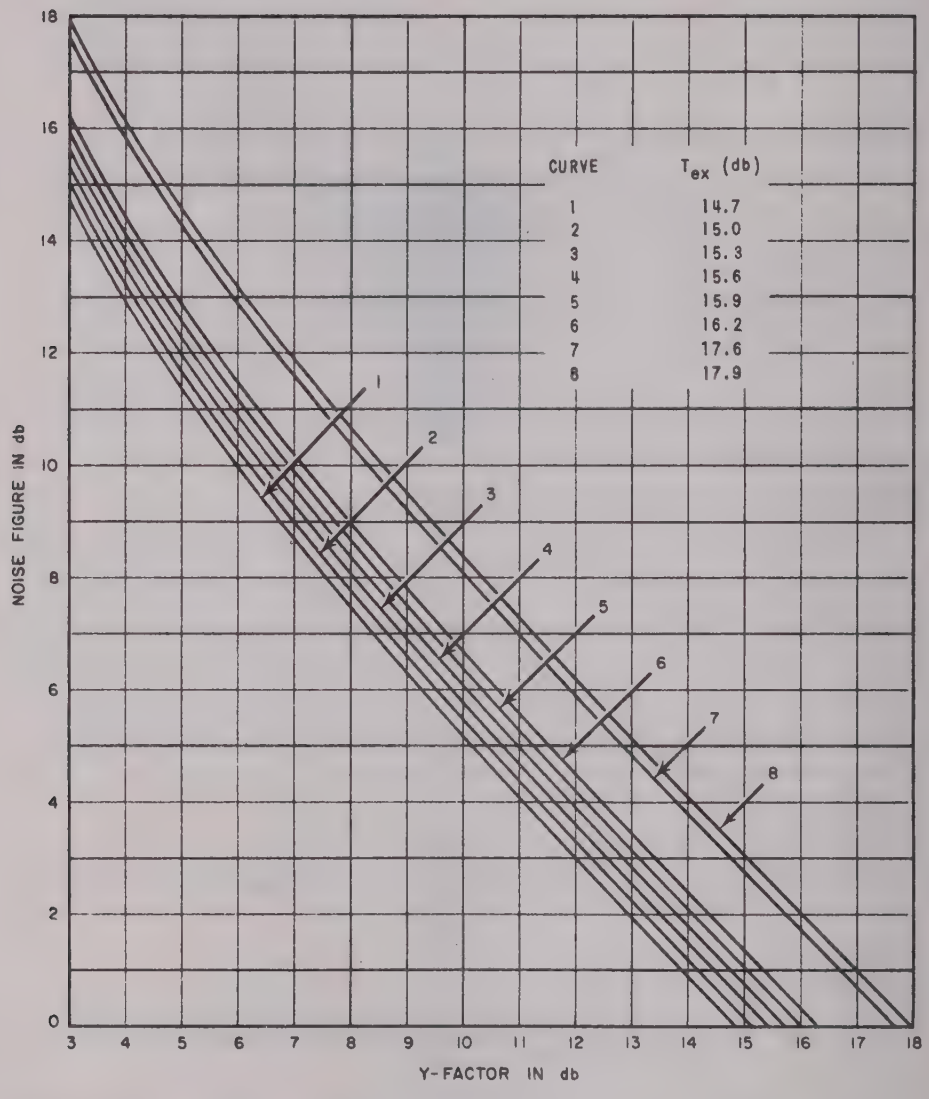


FIGURE 4-11. NOISE FIGURE VS Y-FACTOR FOR VARIOUS DISCHARGE NOISE GENERATORS

SECTION V
THEORY OF OPERATION

5-1 SYSTEM DESCRIPTION

The Type 137 RF Attenuation Calibrator is a highly stable receiver which includes double frequency conversion. The first IF is at 70 MHz (wide band); the second IF is at 30 MHz (narrow band). Basically, however, the receiver system can be divided into two main categories of operation, frequency detection and control, and signal amplitude detection and control. Some portions of the system are functionally common to both categories. These include the preamplifier and postamplifier at 30 MHz, the noise generator, and the 1-kHz modulator. A simplified block diagram of the receiver is shown in Figure 5-1.

The heterodyned signal from the RF mixer is at a nominal 70 MHz; the signal is amplified and then linearly converted to 30 MHz. This operation is performed in the first IF preamplifier and IF mixer. The 30 MHz signal is further amplified in the second preamplifier and then square wave modulated at a 1 kHz rate. The modulated 30-MHz signal is attenuated through a precision waveguide below-cutoff attenuator and then applied to the input of the 30-MHz postamplifier. The output of the noise generator is also applied to the postamplifier input. The noise generator output is basically band limited Gaussian noise. When the attenuator is at its reference setting (0.00 dB), the noise is modulated at a 1-kHz rate. The modulation is in counterphase with the modulation of the preamplifier output. At settings of the attenuator greater than approximately 30.00 dB, the output of the noise generator is applied to the postamplifier without modulation.

When the output level of the noise generator is adjusted according to the procedures described in Section IV, the total noise at the postamplifier input will appear to be unmodulated (attenuator set to 0.00 dB) whereas the IF signal will be square wave modulated. The "unmodulated" noise and modulated IF signal are amplified in the postamplifier and then detected. The output of the second detector will contain a 1-kHz square wave signal and noise. This is further amplified in a narrow-band 1-kHz amplifier and then coherently detected (Reference Normal) or peak detected (Reference Expand). The detected signal is displayed on a taut band, precision, current meter.

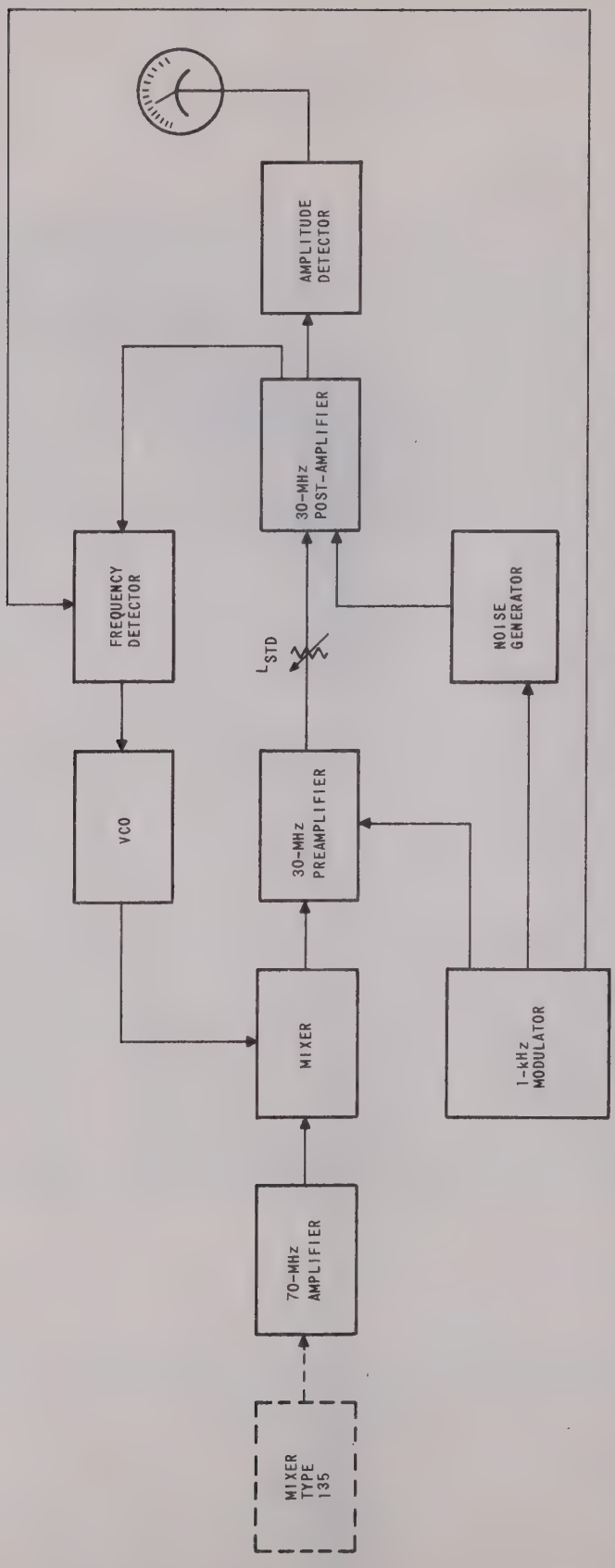


FIGURE 5-1. SIMPLIFIED SYSTEM BLOCK DIAGRAM

Frequency detection and control is an important function of the system. The nominal 70-MHz signal, after being amplified, is frequency converted to the second IF. The second IF is a function of the VCO frequency. The second IF signal is amplified, amplitude modulated, and then applied to a frequency detector. The detector provides a square wave output whose amplitude is proportional to the difference between the second intermediate frequency and 30 MHz (the frequency detector includes a discriminator which is tuned to 30 MHz).

When the second intermediate frequency is not at 30 MHz, a correction voltage is applied to the VCO. The correction voltage will cause the frequency of the VCO to shift in the direction to minimize the difference between the second IF and 30 MHz. For example, if the first IF is at 71 MHz and the VCO frequency is initially at 100 MHz, there would be a 1-MHz frequency error. However, a correction voltage applied to the VCO will cause the VCO frequency to shift to approximately 101 MHz. Actually there would be a residual error of 500 Hz in the VCO frequency; thus the second IF signal would be at 30.0005 MHz. The Type 137 System is designed to reduce frequency errors by as much as 2000 to one.

5-2 SUBSYSTEM DESCRIPTION

5-3 FIRST IF (70 MHz) SUBSYSTEM

The first IF subsystem consists of a 70-MHz amplifier, an RF crystal current monitoring circuit, a 70-MHz band-pass filter, and a diode peak detector. A block diagram of the 70-MHz subsystem is shown in Figure 5-2.

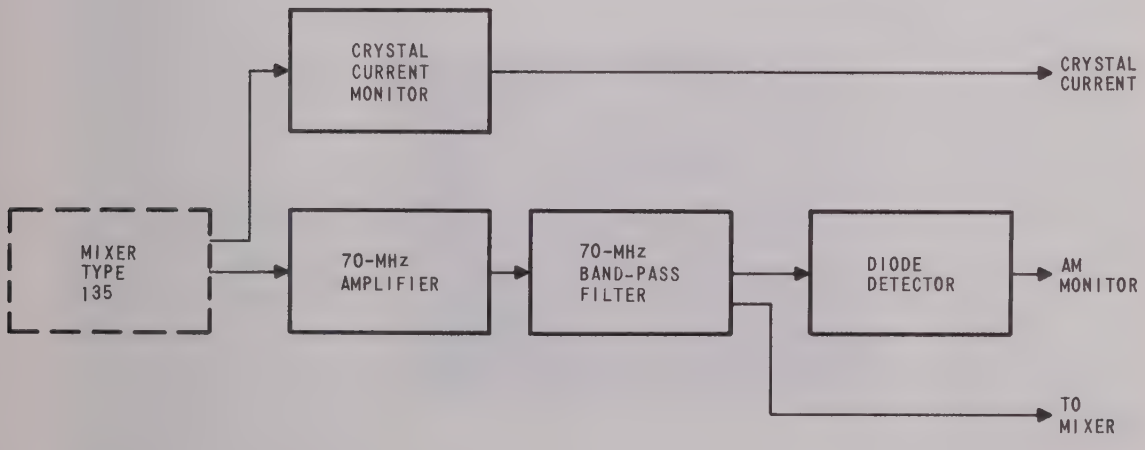


FIGURE 5-2. 70-MHz SUBSYSTEM BLOCK DIAGRAM

The function of this portion of the system is to linearly amplify the IF signal from the RF mixer output. It is extremely important that the amplification be constant over the entire range of input signal levels. Since the RF signal level, at the mixer input, can vary from approximately -15 dBm to -115 dBm, the 70-MHz preamplifier has been designed for linear operation up to -21 dBm (a 6-dB mixer convertion loss is assumed).

A band-pass filter has been utilized to provide the selectivity required to attenuate unwanted spurious signals. This is especially important during initial frequency lock-on. A description of this is given in paragraph 4-17. In order to ensure the accuracy of the RF attenuation measurement when frequency drift in the RF source occurs it is necessary to have a flat frequency response in the filter pass band.

Figure 5-3 is a photograph of an oscilloscope display of the detected filter output under swept conditions. A flat frequency response has been achieved. The diode peak detector is used as an aid in tuning the filter. It is also used in performing amplitude modulation measurements. The measurement description is given in paragraph 4-34.

The filtering in the RF crystal current monitoring circuit provides isolation between the 70-MHz signal and the crystal current display circuits.

5-4 SECOND IF (30 MHz) SUBSYSTEM

The second IF subsystem consists of a 30-MHz preamplifier, a waveguide below-cutoff precision attenuator, a band limited Gaussian noise source, a 30-MHz postamplifier, and a second detector.

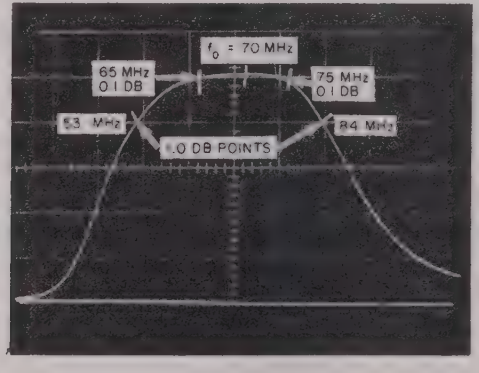


FIGURE 5-3. FREQUENCY RESPONSE OF 70-MHz AMPLIFIER

The functions of this portion of the system are to amplify the IF signal from the IF mixer output, to provide a capability for changing the signal level by a precise increment, and to provide an output signal corresponding to a given input signal level.

The 30-MHz preamplifier linearly amplifies the IF signal from the preamplifier converter. Considerations regarding linearity are quite important for this unit. The amplifier is capable of handling input signals as high as -10 dBm. Having 25 dB of gain, it can provide a linear output of as high as +15 dBm. An electronic switch is included in the amplifier. This enables the output of the amplifier to be 100 percent square wave modulated.

The 30-MHz postamplifier amplifies the IF signal originating from the mixer output. It includes an adjustable gain control, DETECTOR LEVEL, having at least 50 dB of range. The bandwidth of this unit is approximately 1 MHz. Its bandwidth has been chosen to be narrower than that of the preamplifier preceding it and also less than the bandwidth of the noise generator. Therefore, the postamplifier serves as a "window" for the noise coming from the signal channel and the noise generator. The postamplifier is operated in its linear range when the indicator is adjusted to be in the area marked "Det Lev." The reason for adjusting the amplifier gain to a linear range is to avoid saturation at low signal-to-noise ratios. Saturation could result in a change of the noise statistics and thereby introduce an RF attenuation measurement error.

The series IF substitution method for performing RF attenuation measurements requires an attenuation standard at an intermediate frequency. In the Type 137 a precision waveguide below-cutoff attenuator is used as the attenuator standard. The accuracy of this standard can be affected by the impedances which terminate its ports. Thus this system has been designed so that the attenuator is operated with a matched source and load. TNC connectors are used on the attenuator in order to minimize leakage at the ports and to provide mechanical stability of the electrical connection. This type of connector has extemely low leakage, typically less than 125 dB below the signal power.

The noise stabilization technique extends the RF measurement range of the IF series substitution system. The range is extended primarily because the detected output is unique for a given signal level and gain setting. The uniqueness is due to the fact that the noise level at the detector is constant. The noise level is stabilized at a constant level by the addition of a precise noise power at the postamplifier input. An extremely important consideration, regarding the accuracy of an RF attenuation measurement, is the change of output impedance of the noise generator when it is switched from an on to an off state. A 10-percent change in the impedance of the noise source could introduce a measurement error as large as 0.11 dB. In the Type 137 an impedance adjustment is provided so that no error occurs when the noise generator is switched. This adjustment can be performed very simply while the system is operating.

5-5 AUDIO SUBSYSTEM

The detected output of the IF postamplifier is further amplified and detected in the audio subsystem and then displayed on a meter or recorder. Figure 5-4 is a block diagram of the audio subsystem.

The 1 kHz amplifier has a square wave input but, due to its narrow bandwidth, has a sine wave output (1 kHz monitor). The dynamic range of this narrow band (150 cycles) amplifier has been designed so that approximately 99 percent of the time noise voltages will not saturate the amplifier. If saturation occurred the noise statistics would change and an error could result.

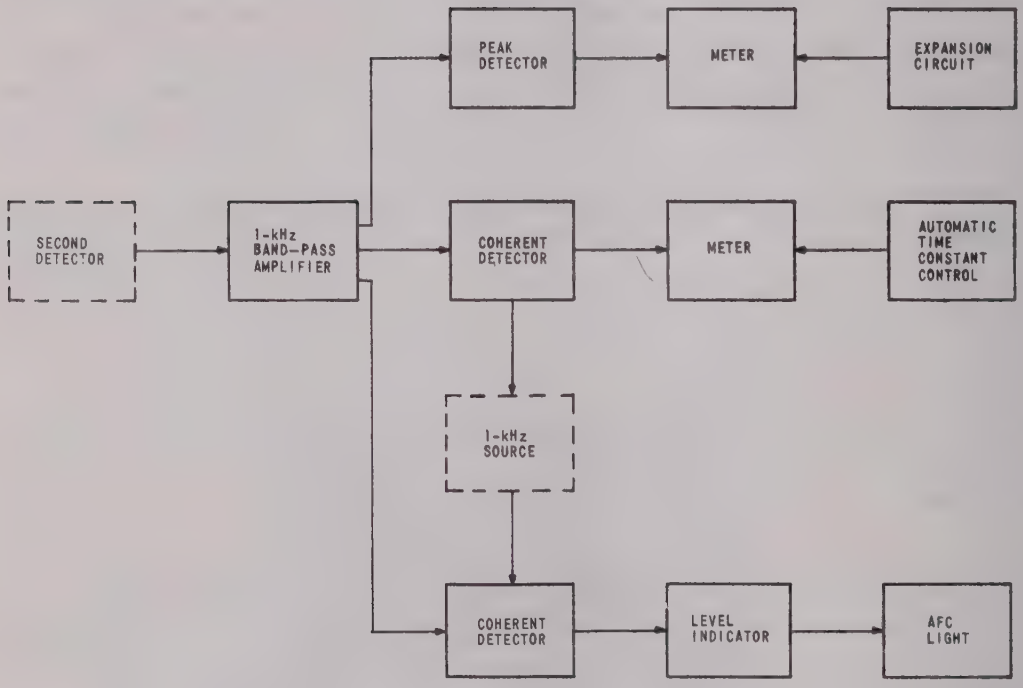


FIGURE 5-4. AUDIO DETECTOR SUBSYSTEM

Either a peak or a coherent detector is used as the system third detector. When the peak detector is used, the REFERENCE EXP switch is depressed; when the coherent detector is used, the REFERENCE NORM switch is depressed. In the EXP mode, the system resolution is typically 0.003 dBm per meter scale division. Peak detector is used to aid in achieving a system stability consistent with this resolution. This detector is insensitive to phase changes in the amplifiers and modulating signal.

At low signal-to-noise ratios the resolution deteriorates in the EXP mode. To improve the resolution a coherent detector is used as a third detector. The RF signal level at which the coherent detector would normally be used is -90 dBm to -120 dBm. In addition, the coherent detector is used when setting the level of the internal noise generator. In this case the level is set so that a null is obtained on the meter.

At very low signal-to-noise ratios a large time constant is required. In fact, as the signal level is reduced a larger time constant is desirable. In the Type 137, an automatic time constant control is incorporated. This control is gaged with the audio gain control, so that as the gain is increased the time constant is also increased.

The audio detection subsystem is also used to indicate the presence of a 30-MHz signal. If a signal is present in the 30 MHz subsystem, it is amplified and detected. The detected signal is further amplified and then coherently detected. Coherent detection is utilized since it is capable of producing a detected output proportional to the RF signal even at levels as low as -115 dBm. The output of the detector is fed to a voltage level indicator. If the output is above approximately 10 mv the AFC indicator will light. If a 30-MHz signal is present and the detected output is below 10 mv the indication on the REFERENCE NORM position will be too low to be very useful and therefore the AFC indicator would not light.

5-6 AFC SUBSYSTEM

The automatic frequency control (AFC) loop compensates for frequency drift in either RF source.

The VCO frequency is automatically adjusted such that a 30-MHz signal frequency is maintained. The loop can respond to RF signal levels as low as -115 dBm. A block diagram of the AFC loop is shown in Figure 5-5. The amount of correction the loop can provide is derived below.

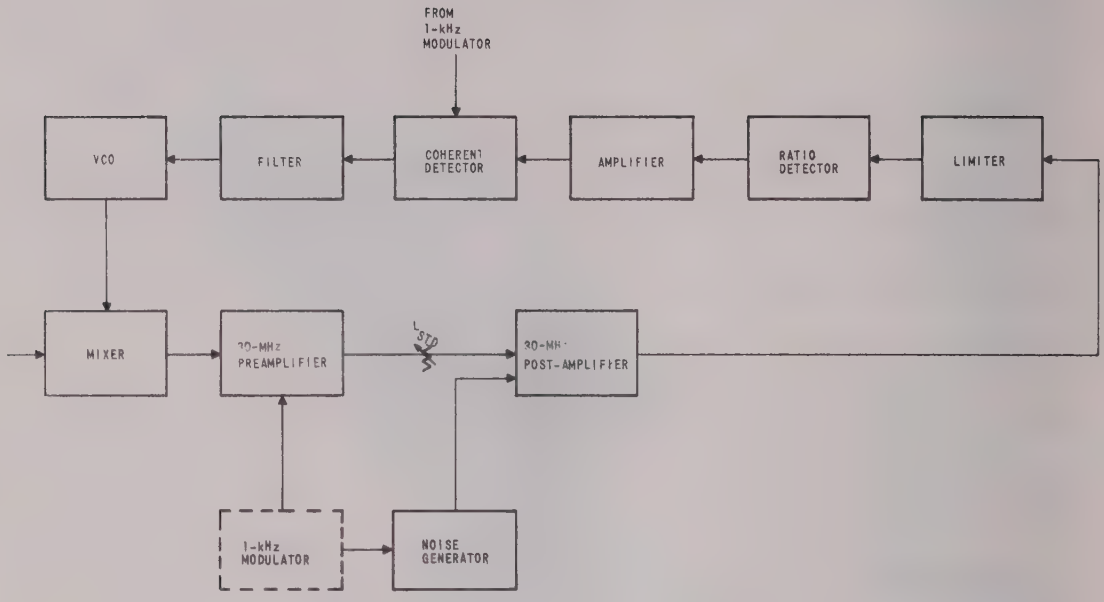


FIGURE 5-5. AFC LOOP BLOCK DIAGRAM

Referring to Figure 5-6, the mixer output frequency, f2, in MHz, is:

$$f_2 = f_{VCO} - f_1 \tag{6}$$

Similarly,

$$V_1 = K_2\left(f_2 - 30\right) \tag{7}$$

where K_2 is expressed in volts/MHz and,

$$f_{VCO} = 100 + K_1 V_1 \tag{8}$$

where K_1, is expressed in MHz/volt

$$f_1 = 70 + \Delta f \tag{9}$$

where Δf is the frequency deviation from a nominal 70 MHz. Substituting equation 7 into 8 we have

$$f_{VCO} = 100 + K_1K_2\left[f_2 - 30\right] \tag{10}$$

Substituting equations 10 and 9 into 6 and solving for f_2 we have,

$$f_2 = 30 - \frac{\Delta f}{1 - K_1K_2} \tag{11}$$

The open loop gain K_1K_2 in the Type 137 is approximately 2500. The VCO sensitivity, K_1, is approximately 2 MHz/volt and the gain, K_2, is approximately 1250 volts/MHz. Since the loop gain is so large it can be seen from equation 11, frequency drift, Δf, of either RF generator can be reduced by a factor of 2500.

At low signal-to-noise ratios the Type 137 has been designed so that K_2 decreases in value as the signal-to-noise ratio decreases. This aids the AFC loop to remain locked when the RF signal level is as low as -115 dBm.

Referring to Figure 5-5, the output of the ratio detector is a square wave whose amplitude is proportional to the frequency difference between the second IF and 30 MHz. The phase of the square wave jumps 180 degrees when the IF frequency passes through 30 MHz. A photograph of the ratio detector output is shown in Figure 5-7.

The filter preceding the VCO has a dual function. It ensures that the loop is stable under all operating conditions and secondly it minimizes the noise voltages which modulate the VCO at very low signal-to-noise ratios. As a result of this filter, the loop can only respond to slow frequency changes which could cause errors in attenuation measurements.

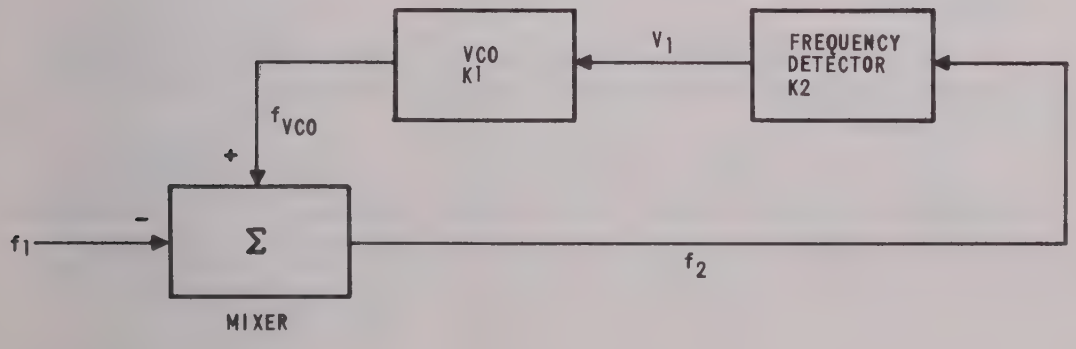


FIGURE 5-6. SIMPLIFIED AFC LOOP

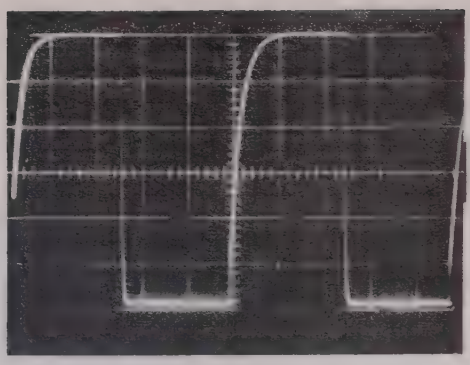


FIGURE 5-7. RATIO DETECTOR OUTPUT

Two additional considerations regarding the loop performance are the capture range and hold-in range. The capture range is a description of a prelock characteristic and the hold-in range describes a postlock characteristic. The capture range is that frequency range at which the second IF can differ from 30 MHz and the loop will lock. The hold-in range is that frequency range at which the first IF can differ from 70 MHz and the loop would still maintain lock. In the Type 137 the capture range is typically 3 MHz, and the hold-in range is typically 35 MHz. At low signal-to-noise ratios the ranges are reduced.

A feature of the AFC loop, when RF attenuation measurements are performed, is that it will lock on to either the upper or lower sideband of the RF mixer output. As a result it is not necessary for the operator to calculate or experiment to determine the phasing or sideband required to achieve lock. In most conventional single frequency conversion systems this is necessary.

5-7 SUBASSEMBLY DESCRIPTION

5-8 CHASSIS

The schematic diagram for the Type 137 receiver is shown in Figure 5-8. This diagram shows the interconnections between the various subassemblies and chassis components.

The DC power for the preamplifier-converter and the RF mixer crystal current are filtered through a double Pi section filter. This filtering plus the shielding of the power cable tends to minimize any external signal leaking into the receiver. Figure 5-9 is a schematic of the filter assembly.

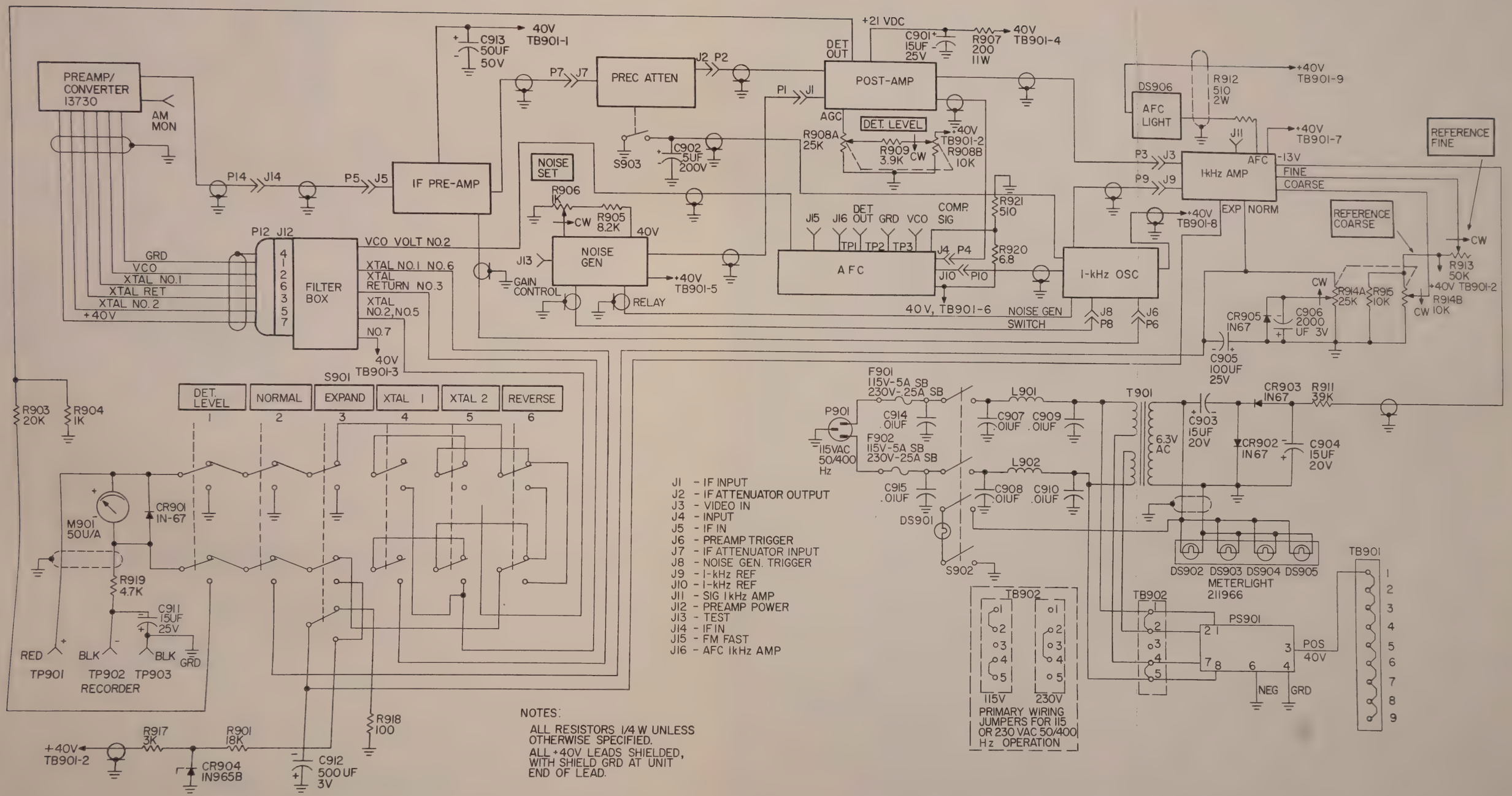
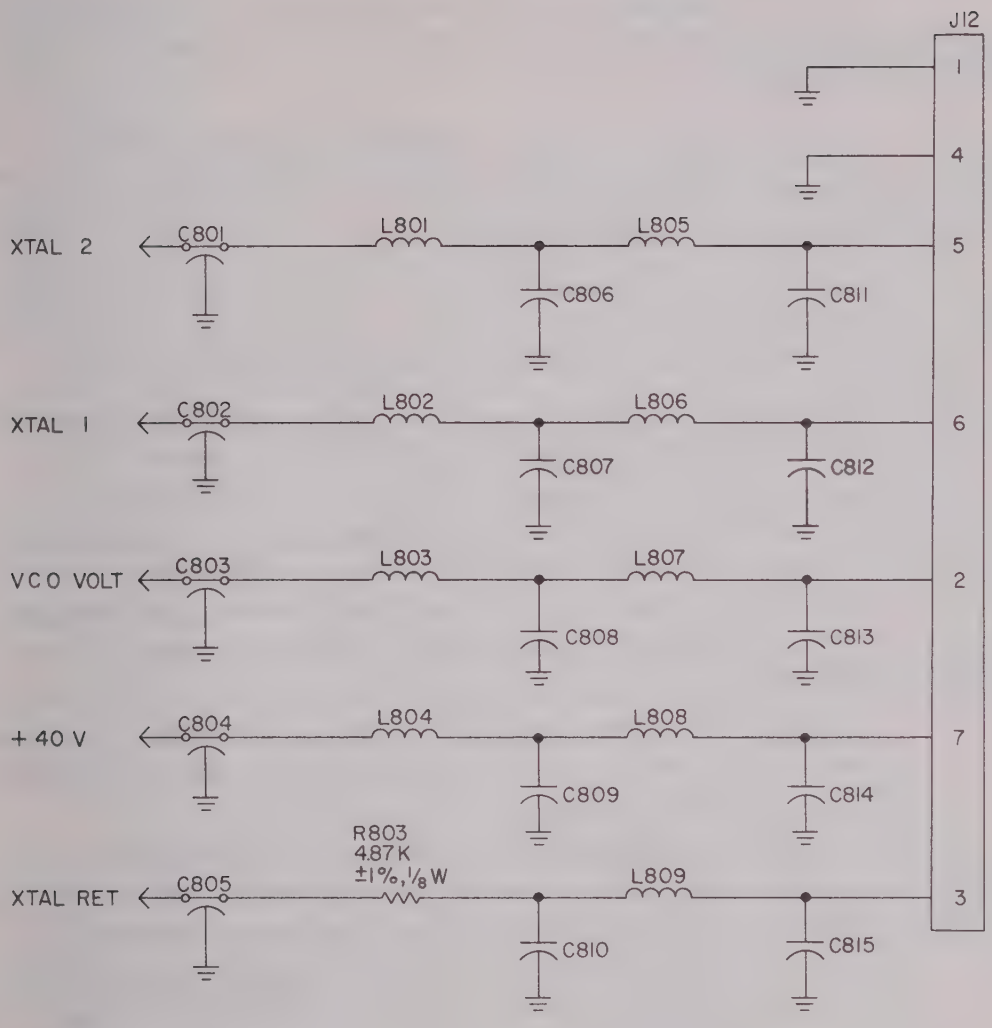


FIGURE 5-8. TYPE 137 PRECISION RF ATTENUATION CALIBRATOR



UNLESS OTHERWISE NOTED
1- ALL CAPACITORS 1000 PF
2- ALL INDUCTORS 1.1 UH

FIGURE 5-9. FILTER SCHEMATIC

As a further precaution against signal leakage and coupling each subassembly is connected to the +40 VDC supply through a separate shielded cable. The connections are made to TB901 and are shown in the schematic.

To minimize leakage within the receiver each subassembly is encased in a shielded enclosure and positioned so that the high and low signal power connections and cables are isolated.

The Type 137 can be used with a nominal line voltage of either 115 or 230 VAC. All models sent from the factory are connected for 115 VAC operation unless otherwise requested. To change from 115 to 230 VAC, it is necessary to reconnect the jumper wires on TB902 as shown in the schematic.

A transformer T901 connects the line voltage to 6.3 VAC. This voltage is used to provide power for the meter lights DS902, 3, 4, and 5. It is also used to obtain -13 volts from the voltage doubler consisting of C903, CR902, CR903, and C904.

Two Pi section filters consisting of C907, C901, C909, C908, L902, and C910 provide filtering of the AC line against unwanted IF and RF signals.

The output indicator of the Type 137 RF Attenuation Calibrator is meter M901, whose function is controlled by switch S901. When S901 is in XTAL 1 or 2, the meter and its multiplier resistor R803 are placed across one of two 100-ohm current-sampling resistors in the preamplifier-converter. The full scale range of the meter in this mode corresponds to 3 ma of crystal current. Polarity is reversed by depressing the REVERSE switch.

When S901 is in Det Level position, the postamplifier detector current is applied to the meter through resistors R903 and R904 which make up a 20-to-1 attenuator. The basic meter movement is 50 ma full scale.

When S901 is in REFERENCE NORM position, the 1 kHz amplifier coherent detector output is applied to the meter. Variable resistor R914A, C905, C906, and CR905 provide a variable time constant for observing the output indication.

When S901 is in REFERENCE EXP position, the peak detector output of the 1-kHz amplifier is applied to the meter. Concurrently, a bucking current obtained from the 40V line and attenuated by R917, CR904, and R901 is also applied to the meter. Extremely good resolution, typically 0.003 dB per scale division, is obtained. Resistor R918 and capacitor C912 provide a fixed time constant for the meter in the expand mode.

The AFC indicator, mounted on the front panel, illuminates when the voltage level indicator in the 1-kHz amplifier has a sufficient input signal. The bulb DS906 operates on approximately 40 ma. Resistor R912 is a current limiting resistor.

Resistor R906 is a variable gain control for the amplifier in the noise generator. A clockwise rotation of this 10-turn potentiometer will reduce the noise output.

Resistor R908A and B is a variable gain control for the 30-MHz postamplifier. A clockwise rotation increases the gain of this unit.

Resistors R915 and R914B provide a variable coarse gain control for the 1-kHz amplifier. A clockwise rotation increases the gain.

A variable fine gain control is provided by resistor R913. A clockwise rotation increases the gain.

5-9 PREAMPLIFIER CONVERTER

A block diagram of the preamplifier-converter is shown in Figure 5-10 and a schematic of the unit is shown in Figure 5-11. This unit includes a wide-band amplifier, a band-pass filter, a broadband mixer, and a voltage controlled local oscillator.

The input of the amplifier is designed to mate with the AIL Type 136 mixers. Two gold-plated beryllium copper clips, mounted on the amplifier printed circuit board, accept the pin output of the double-ended balanced mixers. A variable inductor, L701, provides matching of the output impedance of the mixer to the input of the amplifier in order to achieve a good front end noise figure. The preamplifier consists of two stages of amplification and has a nominal 100 MHz 3 dB bandwidth. The broad bandwidth is obtained through the use of toroidal transformers and high frequency transistors, KMC K3502.

An interstage band-pass filter provides selectivity. It has a center frequency of 70 MHz and provides the amplifier with a bandwidth of 10 MHz with less than 0.1 dB of ripple and a 20-MHz bandwidth with less than 0.5 dB of ripple. The filters consist of L709, L710, L712, C7-4, and C711.

The pads inserted before and after the mixer provide a good impedance match over a 20 MHz band. As a result of the impedance match, the conversion loss of the mixer is flat within 0.03 dB over the frequency range of 65 to 75 MHz. The mixer is doubly balanced and consists of a matched diode quad CR702, CR703, CR704, and CR705 and wide-band transformers T701 and T702. The mixer provides high isolation between the signal, local oscillator, and IF ports.

The voltage controlled oscillator is used as a local oscillator for the mixer. It provides an output of +5 dBm over its entire frequency range. The oscillator is a one-stage, 2N1742, feedback amplifier. The frequency of a oscillation is primarily determined by L720 and the varactor diode CR706, capacitance. Since L720 is fixed, tuning of the oscillator is accomplished by changing the reverse bias on the varactor diode.

The stability of the preamplifier converter is enhanced by the voltage regulation of zener diode CR707. Resistor R721 is a voltage dropping resistor for the diode.

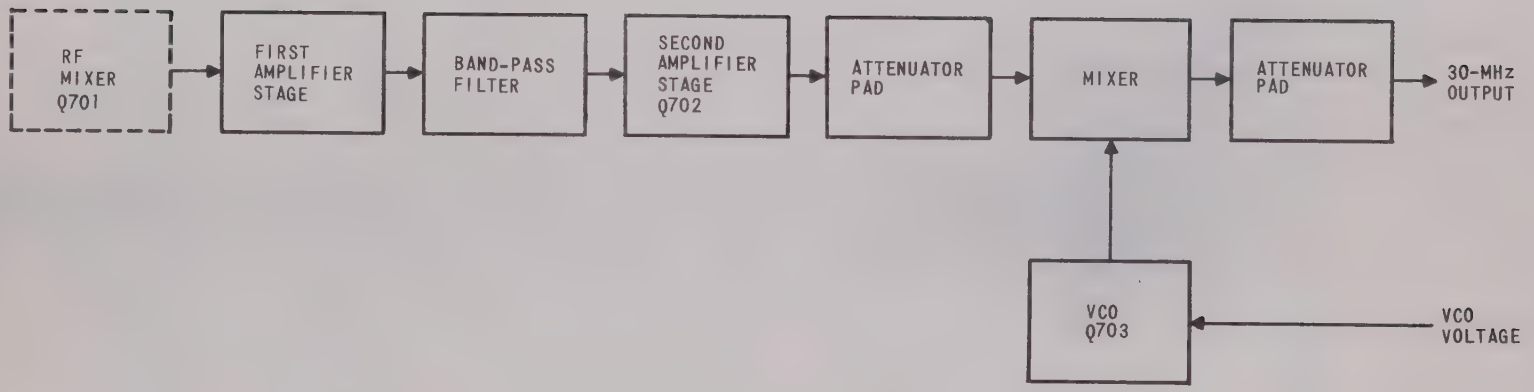
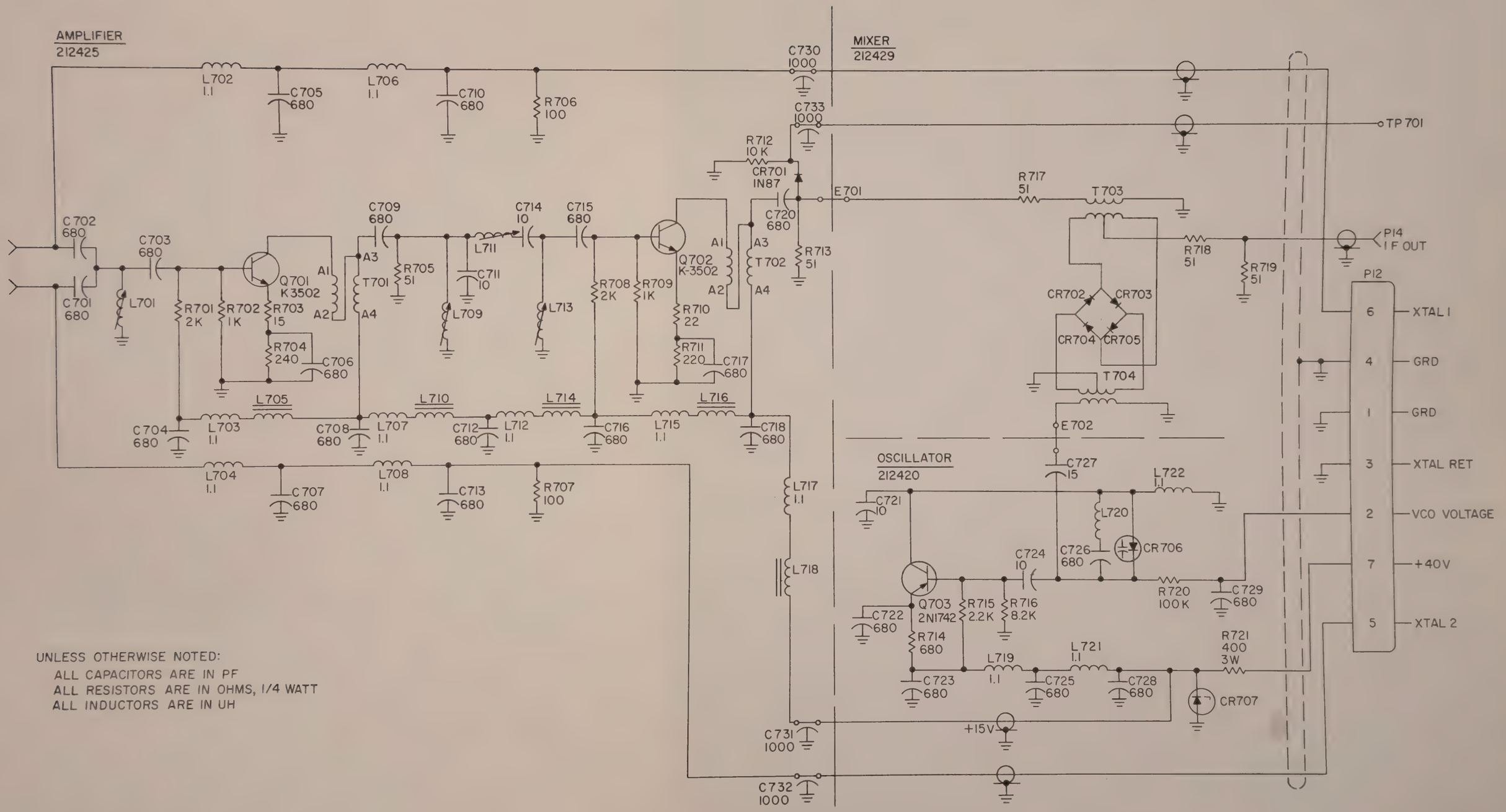


FIGURE 5-10. PREAMPLIFIER-CONVERTER, BLOCK DIAGRAM



UNLESS OTHERWISE NOTED:
ALL CAPACITORS ARE IN PF
ALL RESISTORS ARE IN OHMS, 1/4 WATT
ALL INDUCTORS ARE IN UH

FIGURE 5-11. PREAMPLIFIER-CONVERTER, SCHEMATIC DIAGRAM

5-10 30-MHz PREAMPLIFIER

A block diagram of the 30-MHz preamplifier is shown in Figure 5-12 and a schematic is shown in Figure 5-13. This unit includes a three-stage amplifier and an electronic switch.

The overall power gain of this unit is about 22 dB for signal levels of up to -7 dBm input. All stages are synchronously tuned to 30 MHz by means of variable inductors. Interstage coupling is provided by means of capacitive divider networks. The overall amplifier bandwidth is approximately 2.5 MHz.

The input signal to the preamplifier is obtained from the output of the IF mixer. Since a three-foot length of 50-ohm coaxial cable connects the two units, it is very desirable to have a 50-ohm input impedance looking into the preamplifier. The matching network consisting of C202, C204, L201, and C205 transform the amplifier input impedance to 50 ohms.

The input stage incorporates a KMC K2523 transistor which is optimized for low noise at high currents. Current feedback through resistor R203 provides linear and stable gain for signal levels as high as -7 dBm input.

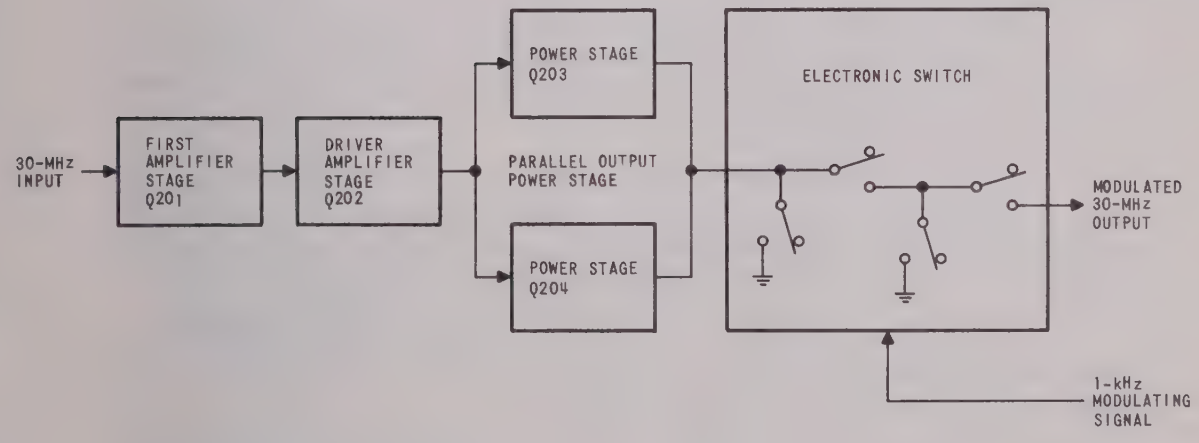


FIGURE 5-12. 30-MHz PREAMPLIFIER BLOCK DIAGRAM

The second stage incorporates a power transistor 2N3309, which serves as a driver for the output stage. This stage is optimized for linear amplification and contains current feedback through resistor R208.

The output stage consists of two parallel connected 2N2950 power amplifiers. Inductor L209, C219, and C221 comprise the tank circuit and also provide a 50-ohm impedance match looking from the output connector.

Modulation of the IF signal is accomplished by the opening and closing of the electronic switch consisting of diodes CR201, 202, 203, and 204. Capacitors C224, C226, and C227 provide an RF bypass to ground. Capacitors C223 and C228 provide coupling. A 1-kHz square wave signal is fed into the "Pulse In" port and turns the switch on when the signal is positive (Diodes CR202 and CR203 conduct). When the signal is negative CR201 and CR204 conduct and turn the switch off. Pin type diodes are used in the switch. These diodes exhibit very little capacitance when reverse biased thus high isolation can be achieved. The switch has approximately 70 dB of isolation in the off state.

5-11 PRECISION ATTENUATOR

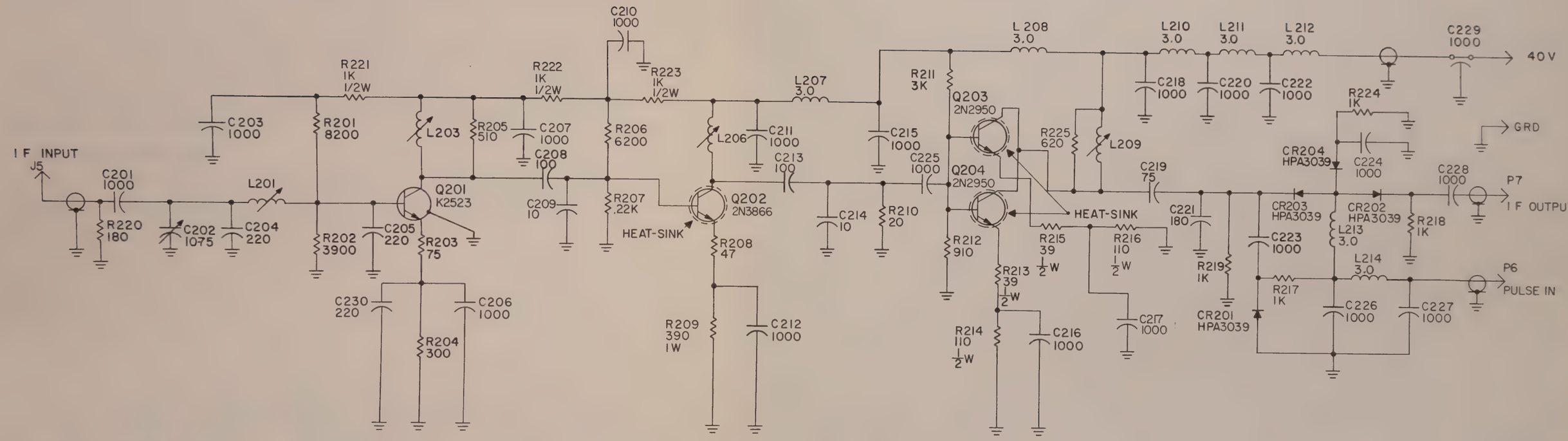
The precision attenuator used in the 137 RF attenuation calibrator consists of a cylindrical cavity whose diameter is such that it forms a waveguide well below cutoff at the 30-MHz operating frequency. The launch coil is part of a piston that travels in an axial direction in the waveguide. This coil is tuned by a series capacitor, and the tuning elements are loaded with a series resistor to provide the proper input impedance.

The receiving coil is fixed at the opposite end of the waveguide. This coil is also tuned with a series capacitor and loaded with a series resistor, thus providing the 50-ohm output impedance.

True wave propagation does not exist in a waveguide below cutoff. The fields are exponentially attenuated down the length of the waveguide with a rate of attenuation that is determined by the transmission mode. For any single mode, the attenuation (in dB) is a linear function of the length of the waveguide.

The effective length of the waveguide can be changed by varying the separation between the coils. Thus, for a particular mode, the attenuation, (in dB) can be read directly from the linear counter dials.

The primary transmission mode of the precision attenuator used in the Type 137 RF Attenuation Calibrator is a TE_{11} mode. This is the lowest mode that will propagate in a circular waveguide; it also has the lowest attenuation constant. If other modes are generated and propagate down the waveguide, they are attenuated faster than this primary mode of transmission.



UNLESS OTHERWISE NOTED:

RESISTOR VALUES ARE IN OHMS ± 5%, 1/4 WATT
CAPACITOR VALUES ARE IN PF
INDUCTOR VALUES ARE IN UH

FIGURE 5-13. 30-MHz PREAMPLIFIER SCHEMATIC DIAGRAM

If the separation between the two coils were reduced to where coupling to the spurious modes is significant, the linearity of the attenuation (in dB) versus distance characteristic of the attenuator would be affected. Consequently, in a practical device of this sort, it is necessary to provide a minimum separation between the radiating and receiving coils and, thus, preserve the accuracy of the attenuator.

This separation naturally introduces a fixed attenuation between the input and output of the precision attenuator which is called the minimum loss of the device. Careful design of the radiating and receiving coils and selection of an optimum waveguide diameter allow such close coupling that the precision attenuator in the Type 137 exhibits a minimum insertion loss of less than 18 dB.

A limit switch is mounted on the attenuator. It is actuated when the piston has traveled a distance corresponding to approximately a 30-dB change from the 0.00 dB setting. When the switch is closed, it actuates a relay which causes the noise generator to operate continuously, that is, no modulation of its output. The relay is actuated by positive 40 volts.

5-12 NOISE GENERATOR

A block diagram of the noise generator is shown in Figure 5-14 and a schematic is shown in Figure 5-15. This unit includes a three-stage amplifier, an electronic switch, and a variable pad.

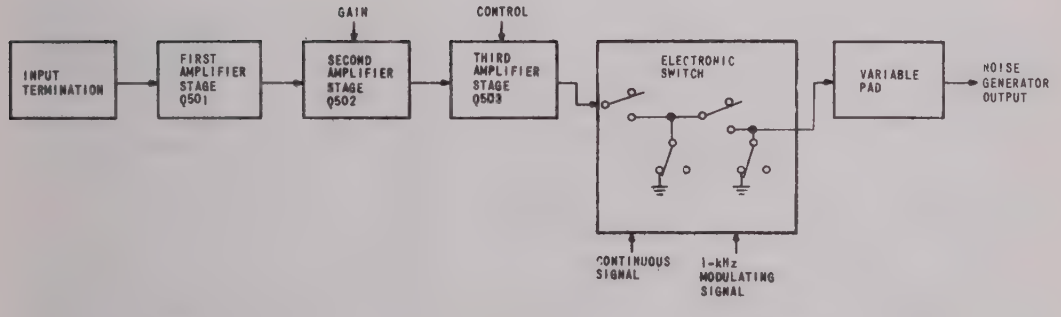


FIGURE 5-14. NOISE GENERATOR BLOCK DIAGRAM

The noise generator is basically an amplifier whose input is terminated in a resistive load, R501. The three stages of amplification employ 2N1742 transistors and are synchronously tuned by varying L501, L504, and L507. Feedback of the first two stages are employed to improve the stability of the noise output. Control of the noise output level is achieved by varying the current through the load diodes CR501 and CR507. The current is varied by adjusting the potentiometer, R906, on the front panel (NOISE SET). As a further means for stabilizing the noise output, a zener diode regulator is used in conjunction with the highly regulated system power supply.

The electronic switch consists of diodes CR502, 503, 504, and 505. Capacitors C523 and C524 provide coupling and C517, C528, and C529 provide bypassing of the IF signal to ground. A positive 1-kHz modulating signal will cause diodes CR503 and CR505 to conduct and therefore open the switch. A negative signal will cause diodes CR502 and CR504 to conduct and therefore close the switch. PIN diodes are utilized because of their very small back-bias capacitance.

A variable pad consisting of R516, R520, and R519 provide isolation and matching of the noise generator. Resistor R516 is adjusted so that the output impedance of the noise generator is constant regardless of the position of the switch. The impedance is adjusted for a maximum change of VSWR of less than 1.02 to 1. The adjustment technique, which is quite simple, is described in the maintenance section. The function of R520 and R519 is to damp any impedance variations which may occur due to aging or any other affect.

5-13 POSTAMPLIFIER

A block diagram of the postamplifier is given in Figure 5-16 and a schematic is given in Figure 5-17. This unit includes a 5-stage amplifier, a second detector, a limiter, and a video and IF emitter follower.

The postamplifier is synchronously tuned to 30 MHz and has a bandwidth of approximately 1 MHz. The postamplifier gain is about 100 dB maximum from the IF input to the second detector input. The input impedance is well-matched, a VSWR of much less than 1.3 to 1. The noise figure is typically 7.0 dB.

The first stage utilizes a 2N2996 transistor, Q1. This transistor has a very good low-noise and high-gain characteristic. The input matching network is a Pi configuration consisting of C1, C2, and C3 and L1.

The intermediate amplifier stages utilizes 2N2996 transistors Q2, Q3, and Q4. Interstage matching is accomplished by using Pi capacitive divider networks. Each stage is tuned by a variable inductor in the collector circuit. The load for each stage consists of a damping resistor and the input impedance of the following stage transformed by the Pi network. The second and third stages are gain controlled by means of diodes which load the collector circuit. As the DC control current through

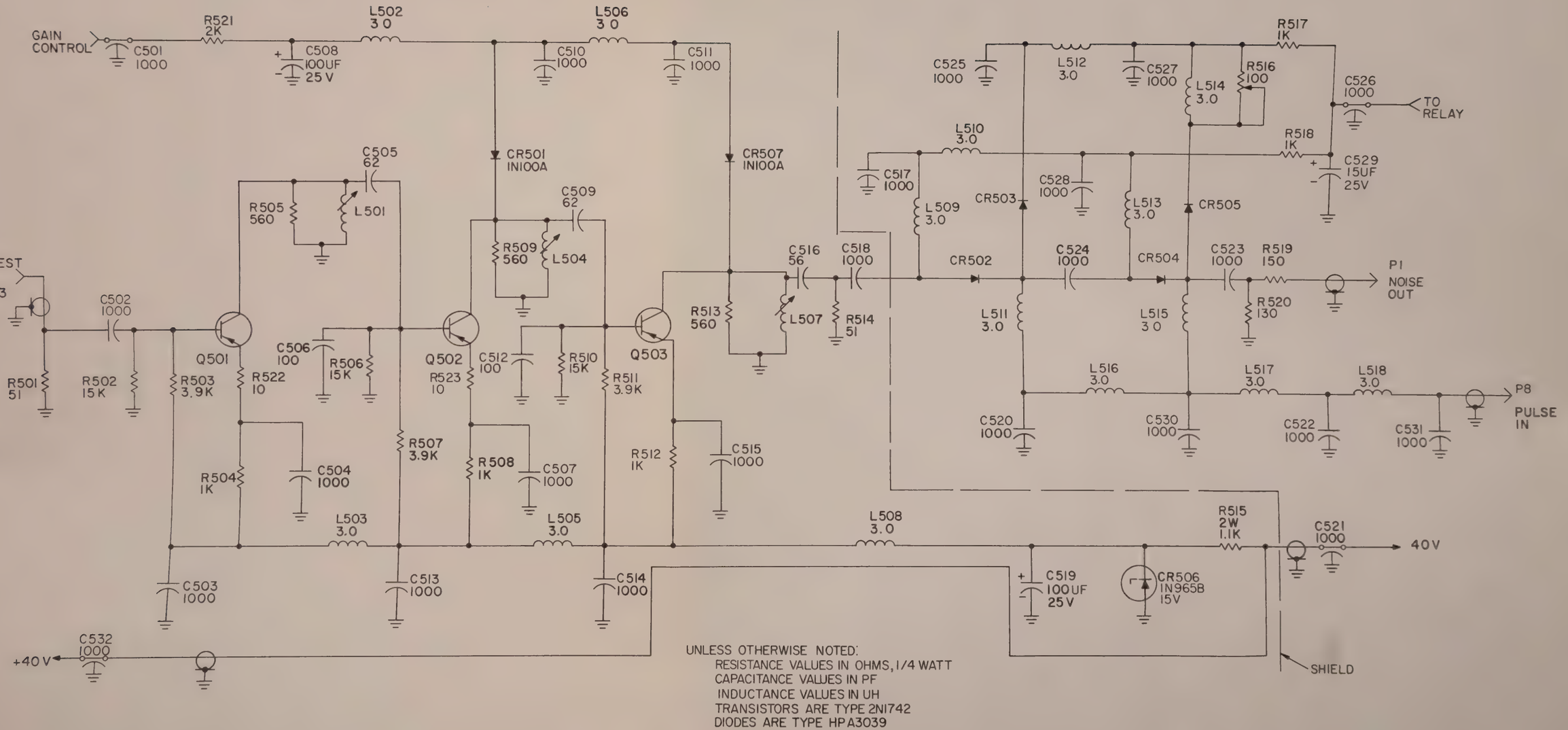


FIGURE 5-15. NOISE GENERATOR SCHEMATIC DIAGRAM

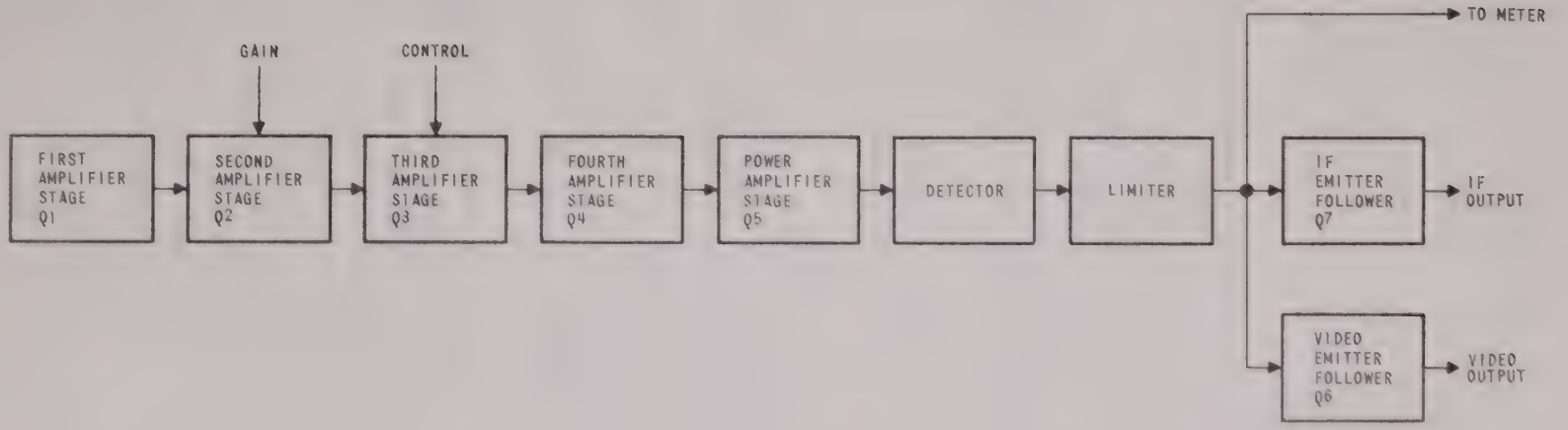


FIGURE 5-16. POSTAMPLIFIER BLOCK DIAGRAM

the diodes is increased the loading increases and the amplifier gain decreases. The diodes are HPA 3039 PIN type. Current control through the diodes is accomplished by varying resistors R903 and R904 on the front panel (DET LEVEL). A dual potentiometer is used to enable the gain control to be a linear function of dial station.

The final amplifier stage utilizes a 2N1141 high-frequency power transistor, Q5. The maximum linear output power of this stage is approximately +3 dBm. Coupling to the second detector and IF emitter follower is through the high Q Pi network consisting of C27, C28, and L12.

The second detector is a simple envelope detector consisting of CR3, a 1N87A germanium diode. Capacitor C29 is the detector filter capacitor, which is loaded by series resistor R20, the display circuits, and the limiter.

The limiter consists of two diodes CR4 and CR5, the combination shunting the second detector output. The limiter functions as an overload maximum voltage control device. In RF attenuation measurements the postamplifier is overloaded when the unknown is removed from the system. The amplifier and limiting diodes provide 100 dB of overload protection.

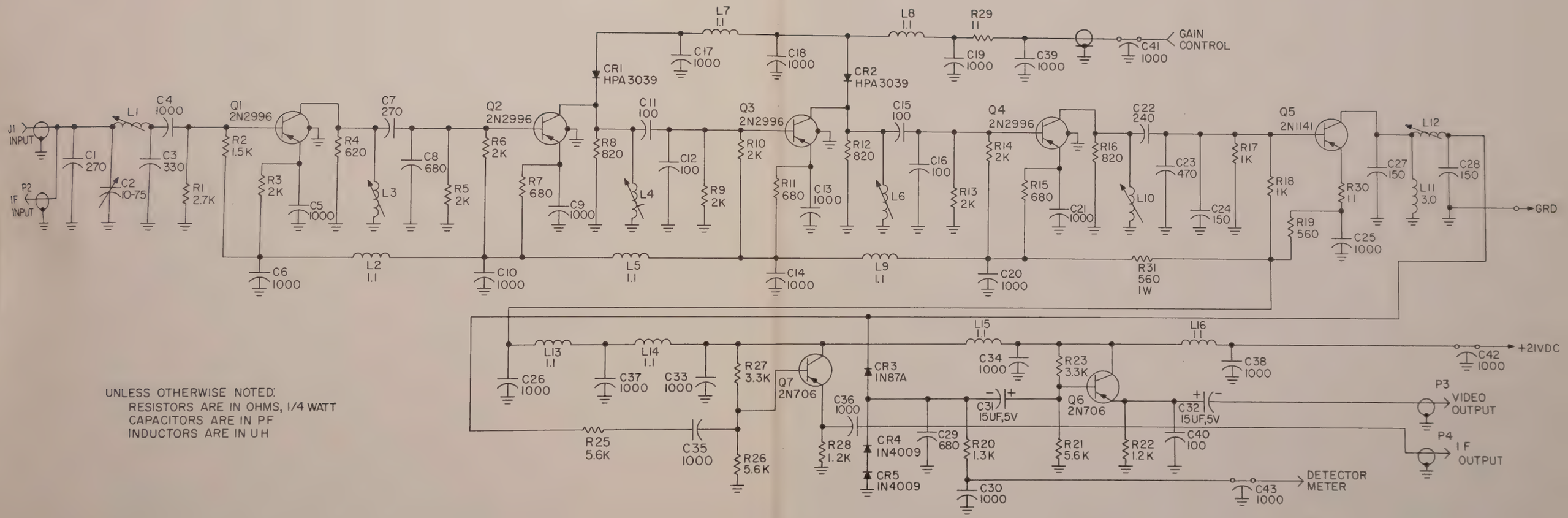
The emitter follower outputs for the IF and video provide a low impedance output and act as a buffer stage between the postamplifier and AFC and Audio units.

5-14 AFC DETECTOR

A block diagram of the AFC detector is shown in Figure 5-18 and a schematic is shown in Figure 5-19. This unit includes a limiter, ratio detector, 1-kHz amplifier, coherent detector, and a DC amplifier.

Three stages of limiting is provided in order to ensure "hard limiting" of the IF signal before it is frequency detected. Limiting first occurs in the third stage Q403, then the second Q402, and finally the first stage Q401. This high degree of limiting is necessary because when performing RF attenuation measurement the signal level can change by as much as 100 dB.

After limiting, the signal is frequency detected in a ratio detector. The ratio detector was first described by Seeley and Avins in the RCA Review, approximately 1938. The detector diodes are CR409 and CR410. Inductor L409 tunes with capacitor C423; its value determines the center frequency of the discriminator. Capacitor C422 is used to balance the stray capacity in the circuit. The high output impedance of the detector is transformed down by an FET source follower. Observation of the output of the source follower is accomplished by connecting an oscilloscope to the rear panel BNC output. Incidental FM of the IF signal can be observed at this point. The IF signal applied to the input of the frequency detector is 100 percent square wave modulated. Thus, for half the modulating cycle the signal is present and for the other half it is not. If a frequency offset exists in the IF, the output of the ratio detector will be a 1-kHz square wave. The amplitude of the square wave will be proportioned to the amount of frequency offset.



UNLESS OTHERWISE NOTED:
RESISTORS ARE IN OHMS, 1/4 WATT
CAPACITORS ARE IN PF
INDUCTORS ARE IN UH

FIGURE 5-17. POSTAMPLIFIER SCHEMATIC DIAGRAM

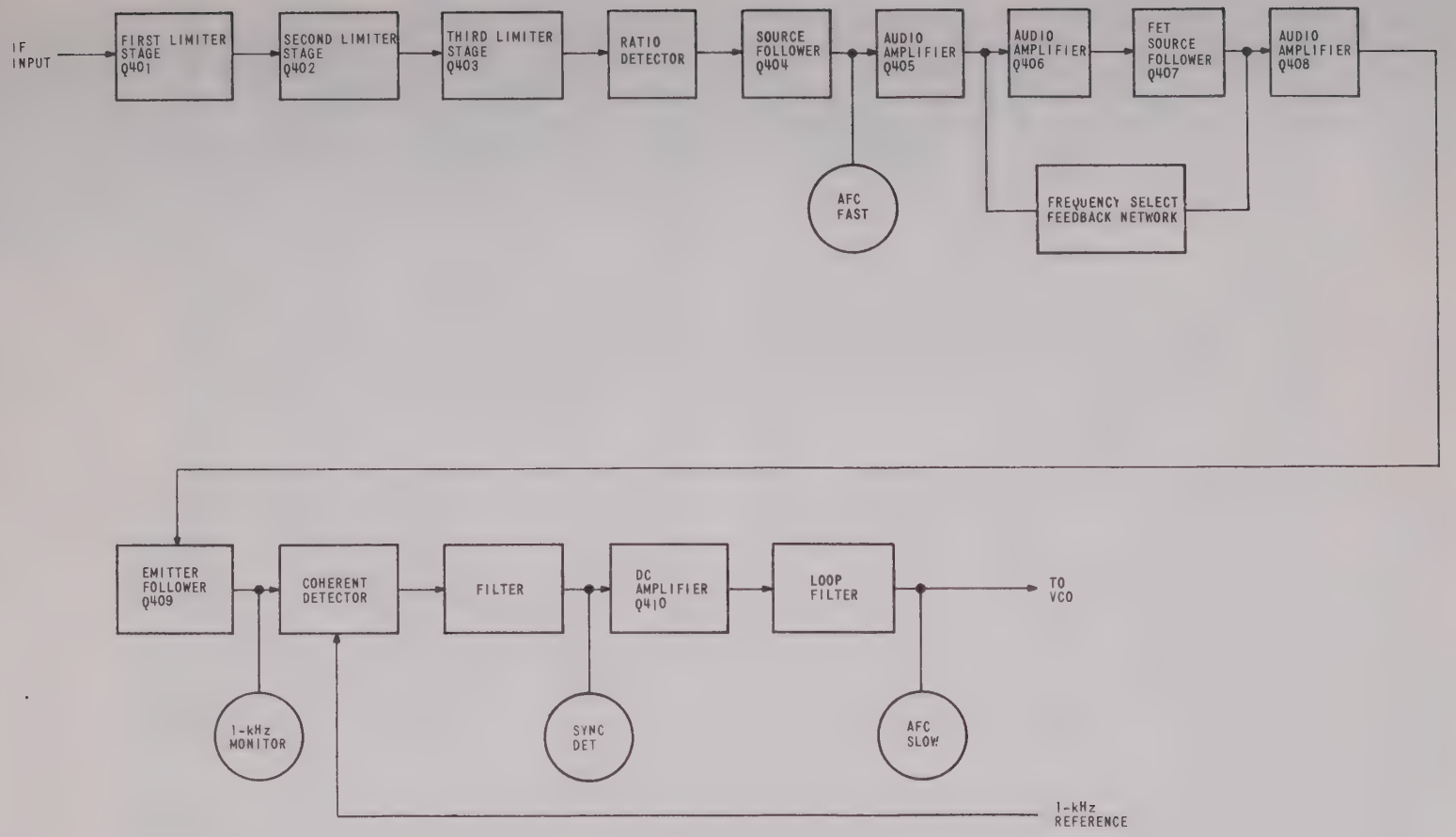


FIGURE 5-18. AFC DETECTOR BLOCK DIAGRAM

The square wave output of the source follower is amplified in three successive stages of amplification. The first, Q405, is provided with an internal gain control, R436. This control is adjusted for an overall frequency detector characteristic of approximately 1200 volts/MHz.

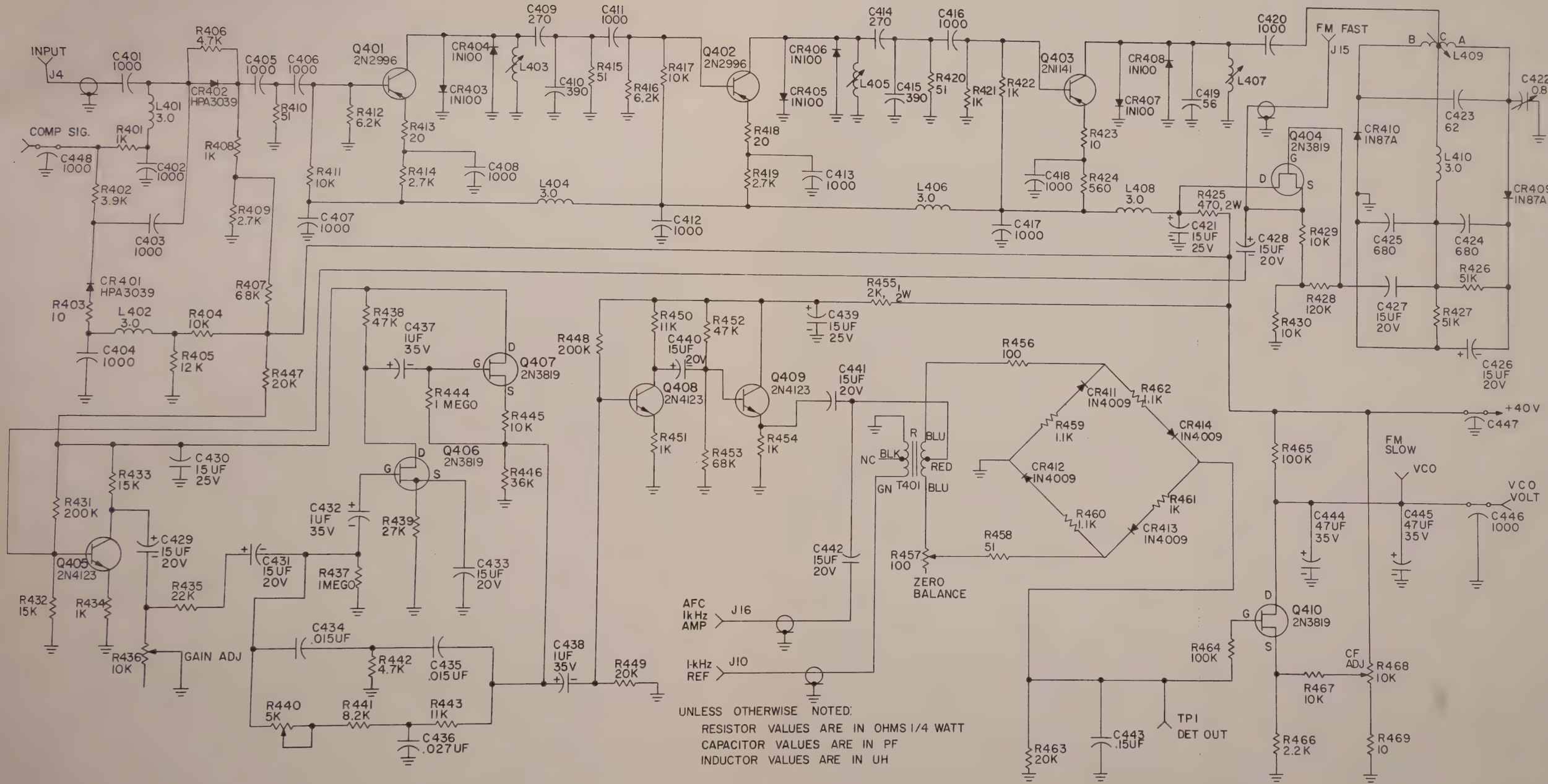
The second stage of amplification includes an FET amplifier, Q406, and source follower Q407. A frequency selective feedback network connects the output of the follower to the amplifier input. This network consists of C434, C435, C436, R440, R441, R442, and R443. Resistor R440 is used to adjust the center frequency of the tuned amplifier. The feedback network is a null network; therefore at the null frequency the amplifier gain will be a maximum since no feedback will exist. At frequencies other than at the null, feedback is present and therefore the amplifier gain is reduced.

The third stage of amplification is provided by Q408. Negative current feedback is obtained through resistor R451. The output of this stage is fed to an emitter follower. The follower is utilized as a driver for the coherent detector.

A 1-kHz signal is applied to the coherent detector. This signal is used as reference for comparison with the signal fed from the driver stage Q409. The reference signal causes the diodes CR411, CR412, CR413, and CR414 to conduct on alternate half cycles. This signal is applied to the diodes through the primary of T401. The resistor in series with the diodes damp the variances in the diode resistance characteristics. Resistor R457 is used for balancing the reference signal drive at the secondary of the transformer.

The detector output will have an average or DC output when the signal from the driver amplifier is applied to the detector and when the phase difference between it and the reference signal is not 90 degrees. A maximum output, for a given input, will occur when the signal is in phase with the reference signal. Since the reference signal and amplified signal are derived from the same source, the 1-kHz oscillator, these two signals will be in phase. The advantage of using the coherent detector is that at low signal-to-noise ratios the detector will discriminate against the noise, for example, the detector DC output will be proportional to its input signal. Noise at the input does not result in an average detector output because the noise is uncorrelated in phase with the reference signal.

The output of the coherent detector is amplified in the DC amplifier, Q410. This amplifier provides sufficient drive signal to enable the VCO to assume its complete frequency range capability. Resistor R468 is a bias control which is set so that for 0 volt DC input the drain quiescent voltage is approximately 10.0 volts. Since this quiescent voltage is a bias for the varactor diode in the VCO, R468 is referred to as a center frequency control.



UNLESS OTHERWISE NOTED:
RESISTOR VALUES ARE IN OHMS 1/4 WATT
CAPACITOR VALUES ARE IN PF
INDUCTOR VALUES ARE IN UH

FIGURE 5-19. AFC DETECTOR SCHEMATIC DIAGRAM

5-15 AUDIO AMPLIFIER/DETECTOR

A block diagram of the audio amplifier/detector unit is shown in Figure 5-20 and the schematic is shown in Figure 5-21. This unit includes a limiter, narrow-band amplifier, two coherent detectors, a peak detector, and a voltage level sensing amplifier.

The limitier consists of two diodes, CR301 and CR302, in shunt and in reverse polarity. The function of the limiter is to prevent overdrive and excessive saturation of the amplifier and coherent detectors.

The first amplifier stage, Q301, has provision for adjusting its gain by means of two front panel controls, REFERENCE COARSE and REFERENCE FINE. The gain is adjusted by varying the current through the diodes CR303 and CR304. These diodes are used as variable resistors shunting the input and output of the amplifier stage.

The next amplifier stage, Q302 and Q303, is a frequency selective stage. The selectivity is determined by the gain in Q302 and the Q of the feedback network. The bandwidth of this amplifier is approximately 150 cps. This stage is identical to that in the AFC detector unit, Q406 and Q407.

The next stage of amplification and buffering is obtained from Q304 and Q305. Current feedback through R323 ensures the stability of this amplifier. The output of the emitter follower drives the coherent detector which provides an output for Reference Normal. The dynamic range of the amplifier and coherent detector has been designed such that no limiting occurs at the highest usable signal level. The presence of noise with its associated voltage spikes have also been accounted for. A three to one sigma criteria has been established. Approximately 98.5 percent of the time a voltage spike would not saturate the amplifier.

The coherent detector obtains its reference signal from the 1-kHz oscillator. The time constant of its output is adjusted by a front panel control ganged to the Reference Coarse adjust.

The signal at the input to the coherent detector is also applied to the Reference Expand channel consisting of amplifier Q306 and emitter follower Q307. The amplification provided by Q306 is a multiplier of the meter scale resolution when the meter is switched from a Normal to Expand Reference position. This multiplying factor is determined by the ratio of resistor values R332 to R333.

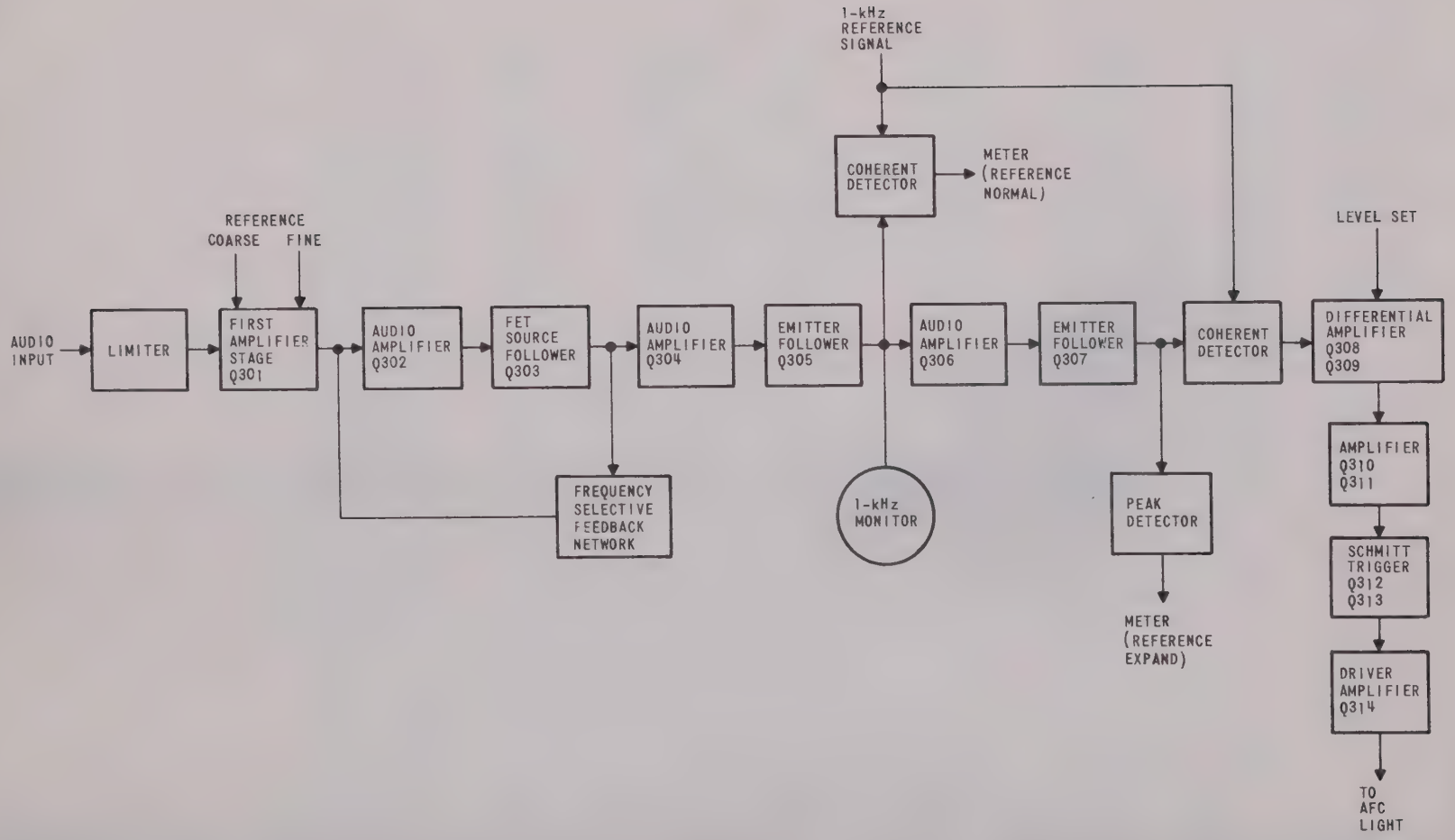
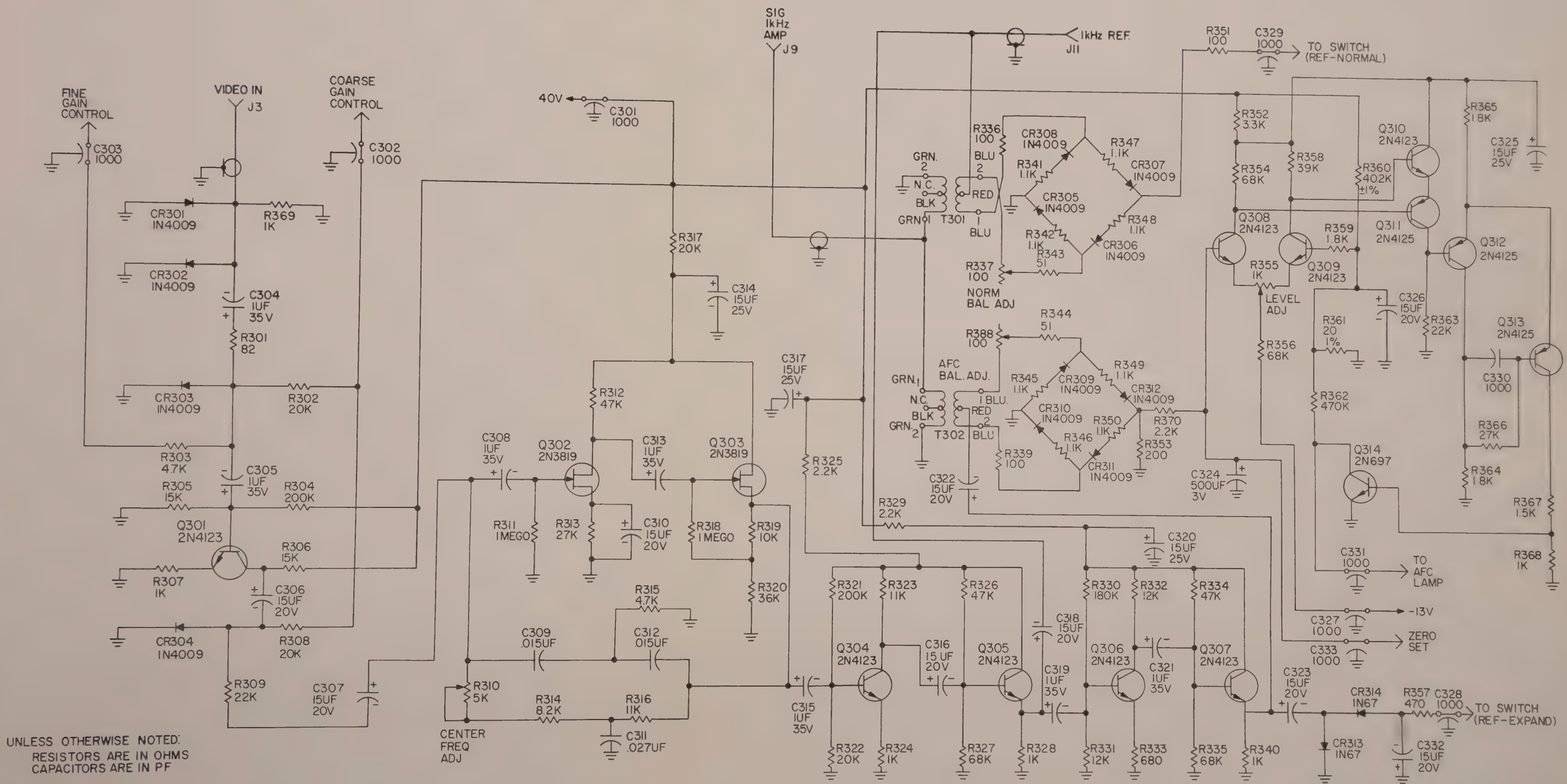


FIGURE 5-20. AUDIO AMPLIFIER DETECTOR BLOCK DIAGRAM



UNLESS OTHERWISE NOTED:
RESISTORS ARE IN OHMS
CAPACITORS ARE IN PF

FIGURE 5-21. AUDIO AMPLIFIER DETECTOR SCHEMATIC DIAGRAM

A function of the Amplifier Detector unit is to provide an indication that the IF signal is present. Moreover, this must be accomplished at signal levels as low as -115 dBm. Therefore a coherent detector was chosen as a means for detecting the presence of the audio signal. The output of the coherent detector is applied to the input of a voltage level indicator. The indicator includes a differential amplifier Q308 and Q309. A reference voltage level is also applied to the differential amplifier. This reference is derived from a -13 volt line and can be adjusted by varying resistor R356. This adjustment is performed in the factory and is set so that a signal level sufficient to given approximately full scale a 1/6 indication in Reference Normal position would also cause the AFC light to illuminate. The output of the differential is amplified and then applied to the Schmitt trigger, Q312 and Q313. The Schmitt trigger will cause the light driver amplifier, Q314, to conduct. The AFC lamp and current limiting resistor, R912, are a collector load for this stage. Resistor R362 is a feedback resistor which enables a reduction in the hysteresis of the switching characteristic.

5-16 1-kHz OSCILLATOR

A block diagram of the 1-kHz oscillator is shown in Figure 5-22 and a schematic is shown in Figure 5-23. This unit includes a 1-kHz oscillator, a squaring circuit, four emitter follower driver stages, and a relay switching circuit.

The basic oscillator consists of Q601 and Q602 amplifier and emitter follower stages and a feedback circuit consisting of C607, R608, C608, C605, R602, and a group of resistors R611, R612, R615, R616, and R617. Adjustment of R616 enables the oscillator frequency to be varied. R615 and R616 are thermistors which compensate for temperature changes in the component values of the feedback circuit. Consequently the frequency stability of the oscillator is quite good even at 120^{o}F. At 100^{o}F the oscillator frequency varies approximately 5 cycles from that at room temperature. Since the audio amplifiers in the rest of the system have approximately a two hundred cycle bandwidth, a 5-cycle variation will not degrade the system. Resistor R604 is a feedback resistor which ensures stable amplifier gain of Q601. The output of the oscillator is applied to an emitter follower, Q603 which serves as a buffer stage. To provide further isolation and to enable sufficient drive signal for the coherent detector an emitter follower, Q604, is included. Similarly, an emitter follower, Q605 is included as the driver for the second coherent detector.

Referring to Figure 5-22, the sinusoidal signal output from Q605 is amplified and shaped into a square wave. Resistor R624 is used for adjusting the symmetry of the square wave for equal on and off time.

The square wave is fed to two emitter followers which provide an output for modulating the noise generator and IF preamplifier. Resistor R635 is an adjustment to ensure the same positive drive signal to the noise generator for the energized and unenergized states of the relay.

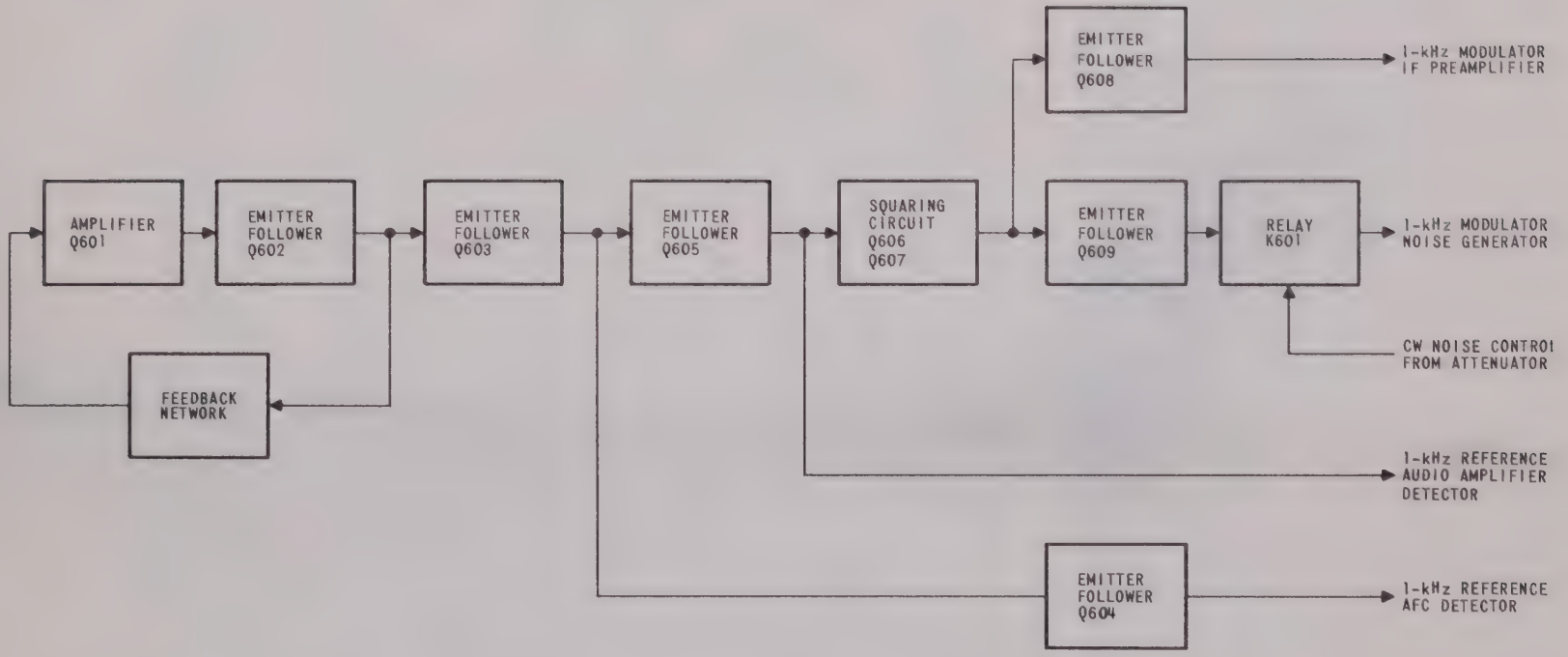


FIGURE 5-22. 1-kHz OSCILLATOR BLOCK DIAGRAM

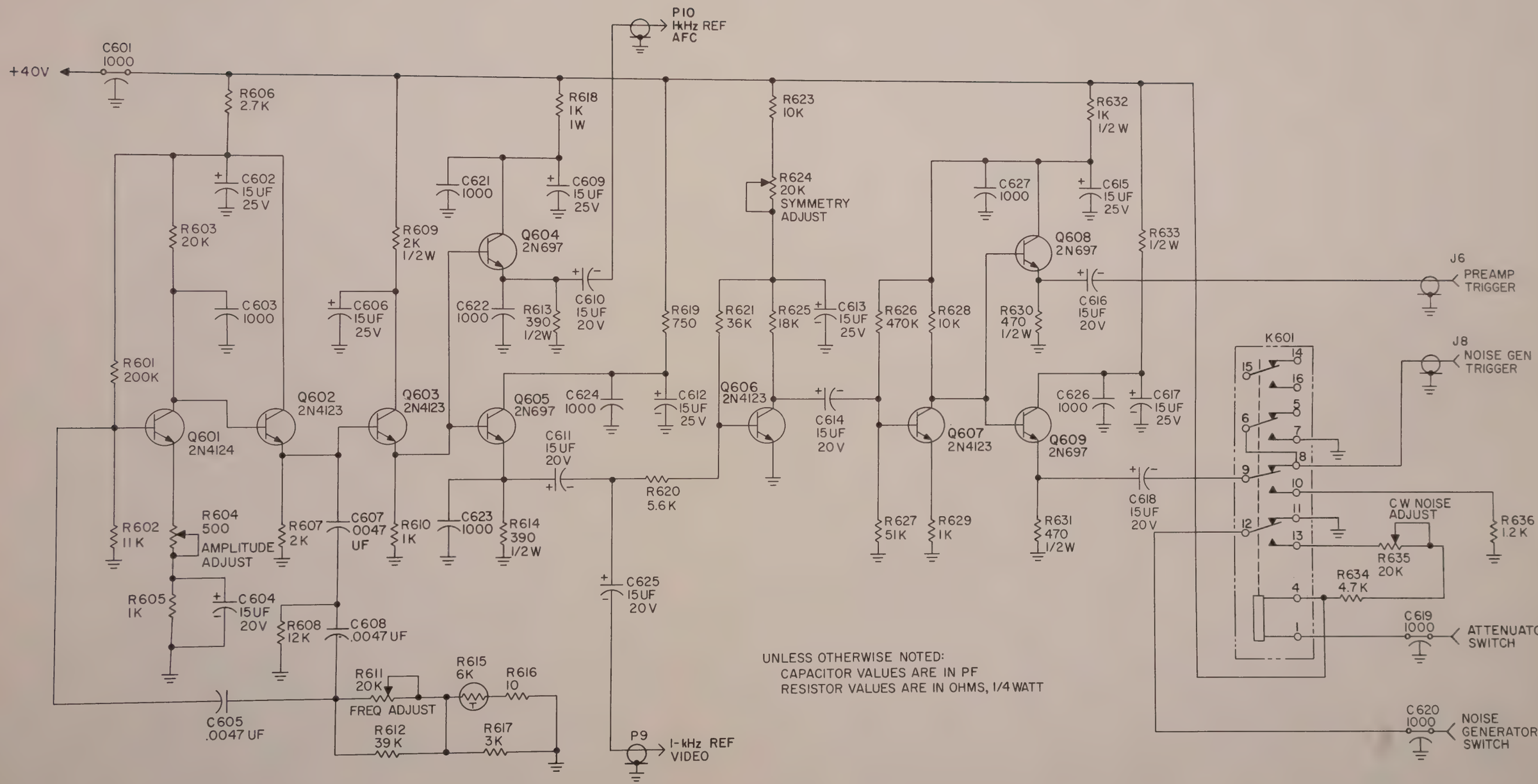


FIGURE 5-23. 1-kHz OSCILLATOR SCHEMATIC DIAGRAM

5-17 POWER SUPPLY

One of two different power supplies may be in your unit. The general specification for either is:

1. DC output voltage 40V $\pm$1V
2. Maximum output current 600 ma
3. Regulation, load and line, 0.1 percent maximum
4. Short circuit protection provided

A schematic for each power supply is given in Figures 5-24 and 5-25.

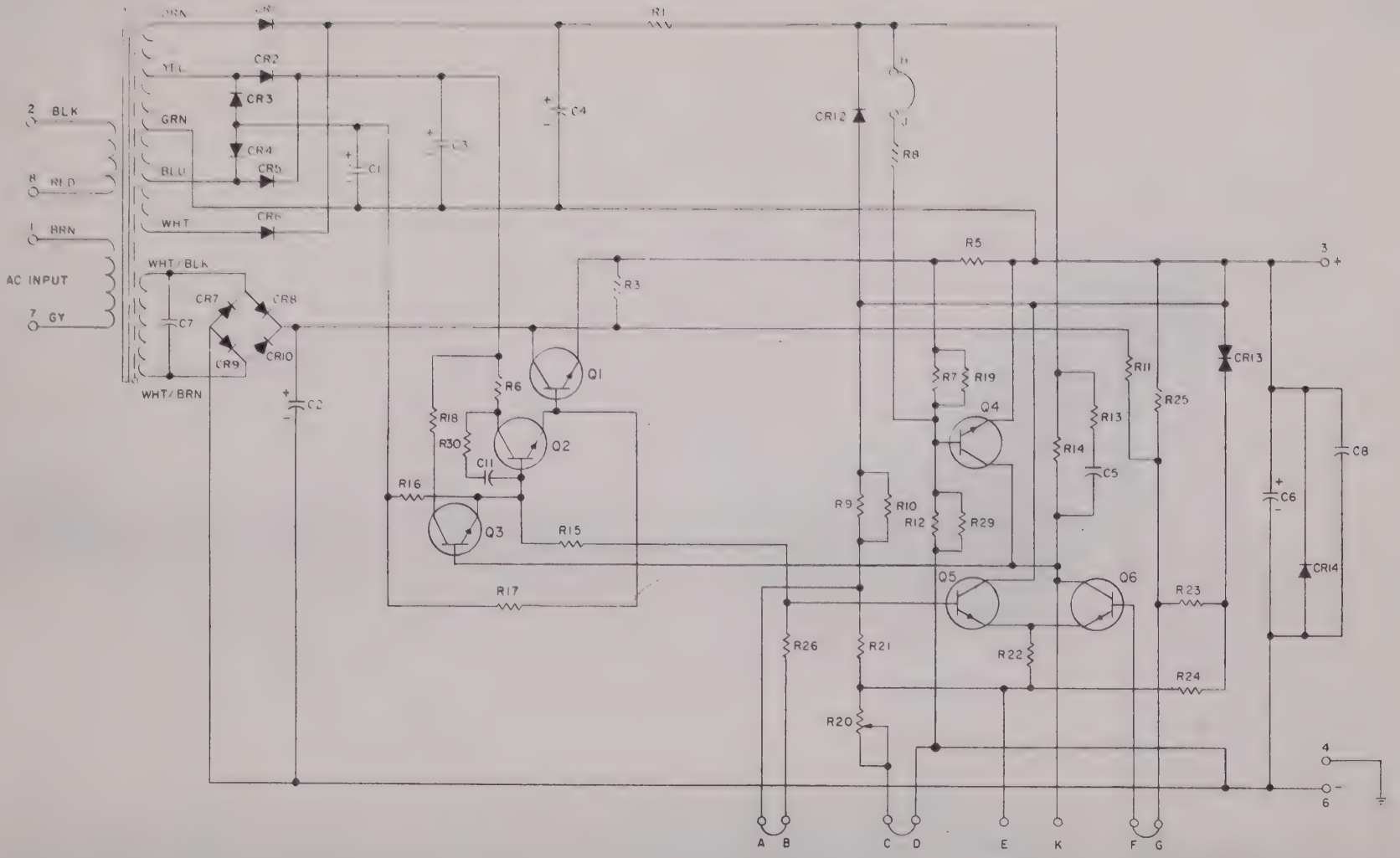


FIGURE 5-24. ERA POWER SUPPLY SCHEMATIC DIAGRAM

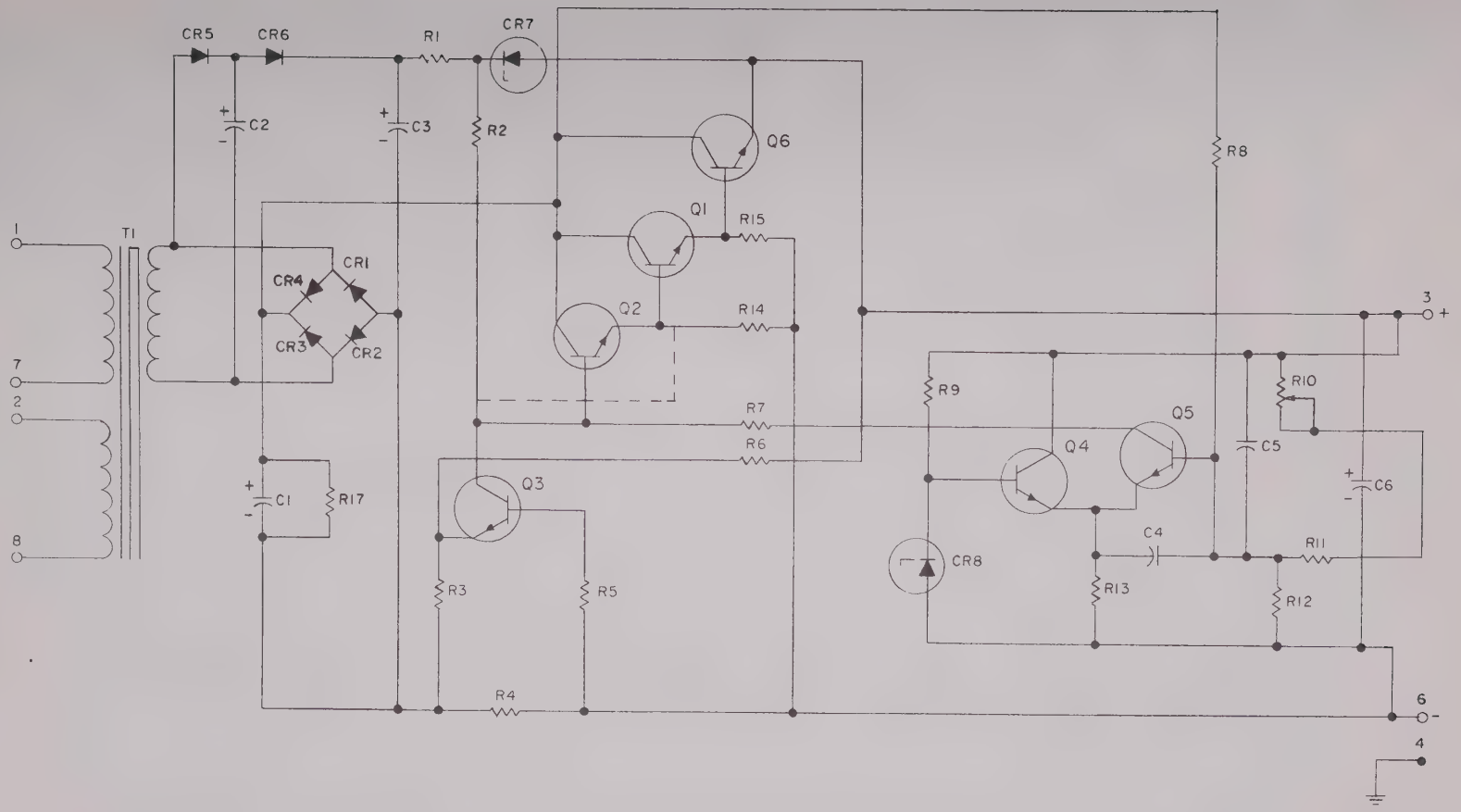


FIGURE 5-25. POWER MATE POWER SUPPLY SCHEMATIC DIAGRAM

SECTION VI
LIST OF REPLACEABLE PARTS

PRECISION ATTENUATOR CALIBRATOR (P/N 13710)

Reference Symbol	Description	Manufacturer	Part Number
C901, 11	Capacitor, electrolytic, 15 μf, 25v	Sprague	TE7205
C902	Capacitor, paper, 0.5 uf, 200v	Aerovox	P8292ZM12
C903, 4	Capacitor, electrolytic, 15 μf, 20v		CS13BE156M
C905	Capacitor, electrolytic, 100 μf, 25v	Sprague	TE1211
C906	Capacitor, electrolytic, 200 uf, 3v	Sprague	TL1071
C907, 14, 15, 8, 90, 10	Capacitor, paper, 0.01 uf, 600v		CK63AW103M
C912	Capacitor, electrolytic, 500 μf, 3v	Sprague	TE1068
C913	Capacitor, electrolytic, 50 μf, 50v	Cornell-Dubilier	BR50-50
CR901, 2, 3	Diode		1N67-
CR904	Diode		1N965B
DS906	AFC light	Chicago Miniature Lamp	CM370
F901, 902	Fuse, Slo Blo, 1A		F02B250V1AS
J14	Connector	Gremar	10858
L901, 2	Inductor	AIL	212612
M901	Meter	AIL	211979
	Precision attenuator	AIL	211808
P5	Connector, TNC	Dage	8000-1
PS901	Power supply	AIL	211965
R901	Resistor, fixed, 18 k, 1/4 w		RC07GF183J
R903	Resistor, fixed, 20 k, 1/4 w		RC07GF203J
R904	Resistor, fixed, 1 k, 1/4 w		RC07GF102J
R905	Resistor, fixed, 8.2 k, 1/4 w		RC07GF802J
R906	Resistor, variable, 1 k	AIL	212106
R907	Resistor, fixed, 200, 11 w	Memcor	MAL-11
R908, 914	Resistor, variable, dual	AIL	115289-15
R909	Resistor, fixed, 3.9 k, 1/4 w		RC07GF392J
R911	Resistor, fixed, 39 k, 1/2 w		RC20GF393J
R912	Resistor, fixed, 510, 2 w		RC42GF511J
R913	Resistor, variable, 50 k	Spectral	MOD530

PRECISION ATTENUATOR CALIBRATOR (P/N 13710) (cont)

Reference Symbol	Description	Manufacturer	Part Number
R915	Resistor, fixed, 10 k, 1/4 w		RC07GF103J
R917	Resistor, fixed, 3 k, 1/4 w		RC07GF302J
R918	Resistor, fixed, 100, 1/4 w		RC07GF101J
R919	Resistor, fixed, 4.7 k, 1/4 w		RC07GF472J
R920	Resistor, fixed, 6.8 k, 1/4 w		RC07GF682J
R921	Resistor, fixed, 510, 1/4 w		RC07GF511J
T901	Transformer	Sterling	ST28029
S901	Switch, push type	AIL	211823
S902	Switch, push type	AIL	211824
	POSTAMPLIFIER (P/N 211735)		
C1	Capacitor, glass, 270 pf	Corning	TY06-271J
C2	Capacitor, variable, 10 to 75 pf	Erie	557-091-N1500-10-15pf
C3	Capacitor, ceramic, 330 pf		CK05CW331K
C4, 5, 6, 9, 13, 14, 17-21, 25, 26, 30, 33-39			CK05CW102K
C7	Capacitor, ceramic, 270 pf		CK05CW271K
C8, 29, 40	Capacitor, ceramic, 680 pf		CK05CW681K
C11, 12, 15, 16	Capacitor, ceramic, 100 pf		CK05CW101K
C22	Capacitor, ceramic, 240 pf	Erie	8141
C23	Capacitor, ceramic, 470 pf	Erie	8161
C24, 27	Capacitor, ceramic, 150 pf		CK05CW151K
C28	Capacitor, ceramic, 150 pf	Erie	8141
C31, 32	Capacitor, electrolytic, 15 μf, 25v	Sprague	TE1205
C41, 42, 43	Capacitor, feedthru, 1000 pf	Allen-Bradley	F132B
CR1, 2	Diode, pin	Hewlett-Packard	HPA-3039
CR3	Diode		1N87A
CR4, 5	Diode		1N4009
P1	Connector, TNC	Dage	8016-1
L1, 3, 10	Inductor, variable	AIL	118244-11
L2, 5, 7, 8, 9, 13, 14, 15, 16	Inductor, molded, 1.1 μh	Speers Carbott	10101-1
L4, 6, 12	Inductor, variable	AIL	118244-1

POSTAMPLIFIER (P/N 211735) (cont)

Reference Symbol	Description	Manufacturer	Part Number
L11	Inductor, molded, 3 μh	Speers Carbon	10100-2
P2, 3, 4	Connector, TNC	Dage	8000-1
Q1, 2, 3, 4	Transistor		2N2996
Q5	Transistor		2N1141
Q6, 7	Transistor		2N706
R1	Resistor, fixed, 2.7 k, 1/4 w		RC07GF272J
R2	Resistor, fixed, 1.5 k, 1/4 w		RC07GF152J
R3, 5, 6, 9, 10, 13, 14	Resistor, fixed, 2 k, 1/4 w		RC07GF202J
R7, 11, 15	Resistor, fixed, 680 ohms, 1/4 w		RC06GF681J
R8, 12, 16	Resistor, fixed, 820 ohms, 1/4 w		RC07GF821J
R17, 18	Resistor, fixed, 1 k, 1/4 w		RC07GF102J
R19	Resistor, fixed, 560 ohms, 1/4 w		RC07GF561J
R20	Resistor, fixed, 1.3 k, 1/4 w		RC07GF132J
R21, 25, 26	Resistor, fixed, 5.6 k, 1/4 w		RC07GF562J
R22, 28	Resistor, fixed, 1.2 k, 1/4 w		RC07GF122J
R23, 27	Resistor, fixed, 3.3 k, 1/4 w		RC07GF332J
R29, 30	Resistor, fixed, 11 ohms, 1/4 w		RC07GF110J
R31	Resistor, fixed, 560 ohms, 1 w		RC32GF561J

PREAMPLIFIER (P/N Z11770)

C201, 3, 6, 7, 10, 11, 12, 15, 16, 17, 18, 20, 22, 23, 25, 26, 27, 28	Capacitor, ceramic, 1000 pf		CK60AW102M
C202	Capacitor, variable, 10 to 75 pf	Erie	557-091-N1500-10-75 pf
C204, 5, 30	Capacitor, ceramic, Z20 pf		CK05CWZ21K
C208, 13	Capacitor, ceramic, 100 pf	Erie	8151
C209, 14	Capacitor, ceramic, 10 pf		
C219	Capacitor, ceramic, 75 pf	Erie	8141
C221	Capacitor, ceramic, 180 pf		CK05CW181K
C224	Capacitor, feedthru, 1000 pf	Allen-Bradley	SS5A
C229	Capacitor, feedthru, 1000 pf	Allen-Bradley	FB2B
CR201, 2, 3, 4	Diode	Hewlett-Packard	HPA-3039
J5	Connector, TNC	Dage	8016-1

PREAMPLIFIER (P/N Z11770) (cont)

Reference Symbol	Description	Manufacturer	Part Number
L201, 6, 9	Inductor, variable	AIL	118244-1
L203	Inductor, variable	AIL	118244-2
L207, 8, 210-214	Inductor, molded, 3 μh	Speers Carbon	10100-2
P6, 7	Connector, TNC	Dage	8000-1
Q201	Transistor	KMC Semi-Cond. Corp.	KZ523
Q202	Transistor		2N3309
Q203, 4	Transistor		2N2950
R201	Resistor, fixed, 8.2 k, 1/4 w		RC07GF822J
R202	Resistor, fixed, 3.9 k, 1/4 w		RC07GF392J
R203	Resistor, fixed, 75 ohms, 1/4 w		RC07GF750J
R204	Resistor, fixed, 300 ohms, 1/4 w		RC07GF301J
R205	Resistor, fixed, 510 ohms, 1/4 w		RC07GF511J
R206	Resistor, fixed, 6.2 k, 1/4 w		RC07GF622J
R207	Resistor, fixed, 22 k, 1/4 w		RC07GF223J
R208	Resistor, fixed, 47 ohms, 1/4 w		RC07GF470J
R209	Resistor, fixed, 320 ohms, 1 w		RC32GF391J
R210	Resistor, fixed, 20 ohms, 1/4 w		RC07GF200J
R211	Resistor, fixed, 3 k, 1/4 w		RC07GF302J
R212	Resistor, fixed, 910 ohms, 1/4 w		RC07GF911J
R213, 15	Resistor, fixed, 39 ohms, 1/2 w		RC20GF390J
R214, 16	Resistor, fixed, 110 ohms, 1/2 w		RC20GF111J
R217, 18, 19	Resistor, fixed, 1 k, 1/4 w		RC07GF102J
R220	Resistor, fixed, 180 ohms, 1/4		RC07GF181J
R221, 2, 3, 4	Resistor, fixed, 1 k, 1/2 w		RC20GF102J
R225	Resistor, fixed, 620 ohms, 1/4 w		RC07GF621J

1 kHz AMPLIFIER (P/N 212150)

C301, 2, 3, 27, 28, 29, 31, 33	Capacitor, feedthru, 1000 pf	Allen-Bradley	FB2B
C304, 5, 8, 12, 15, 19, 21	Capacitor, electrolytic, 1 μf, 35v	Sprague	150D105 × 9035A2
C306, 7, 10, 16, 18, 22, 26, 36	Capacitor, electrolytic, 15 μf, 20v		CS13BE156
C309, 12	Capacitor, mica, 0.015 μf	Westcap	4M153K
C311	Capacitor, mica, 0.027 μf	Westcap	4M273K
C314, 17, 20, 25	Capacitor, electrolytic, 15 μf, 25v	Sprague	TE1205

1 kHz AMPLIFIER (P/N 212150) (cont)

Reference Symbol	Description	Manufacturer	Part Number
C324	Capacitor, electrolytic, 15 μf, 25v	Sprague	30D507G003DF2
C330	Capacitor, ceramic, 100 pf		CK0TCW101K
CR301 thru 312	Diode		1N4009
CR313, 14	Diode		1N67
J3	Connector, BNC		VG1094V
J9, 11	Connector, BNC		VG1098A/U
Q301, 4 thru 10	Transistor		2N4123
Q302, 3	Transistor		2N3819
Q311, 12, 13	Transistor		2N4125
Q314	Transistor		2N647
R301	Resistor, fixed, 82 ohms, 1/4 w		RC07GF820J
R302, 8, 17, 22	Resistor, fixed, 20 k, 1/4 w		RC07GF203J
R303	Resistor, fixed, 4.7 k, 1/4 w		RC07GF472J
R304, 321	Resistor, fixed, 200 k, 1/4 w		RC07GF204J
R305, 6	Resistor, fixed, 15 k, 1/4 w		RC07GF153J
R307, 24, 28, 40, 68, 69	Resistor, fixed, 1 k, 1/4 w		RC07GF102J
R309, 63	Resistor, fixed, 22 k, 1/4 w		RC07GF223J
R310	Resistor, variable, 5 k, 1/2 w	Bourns	3307P
R311, 18	Resistor, fixed, 1 m, 1/4 w		RC07GF105J
R312, 26, 34	Resistor, fixed, 47 k, 1/4 w		RC07GF473J
R313, 366	Resistor, fixed, 27 k, 1/4 w		RC07GF273J
R314	Resistor, fixed, 8.2 k, 1/4 w		RC07GF822J
R315	Resistor, fixed, 4.7 k, 1/4 w		RC07GF472J
R316, 323	Resistor, fixed, 11 k, 1/4 w		RC07GF113J
R319	Resistor, fixed, 10 k, 1/4 w		RC07GF103J
R320	Resistor, fixed, 36 k, 1/4 w		RC07GF363J
R325, 29, 70	Resistor, fixed, 2.2 k, 1/4 w		RC07GF222J
R323, 35, 54, 56	Resistor, fixed, 68 k, 1/4 w		RC07GF683J
R330	Resistor, fixed, 180 k, 1/4 w		RC07GF183J
R331, 2	Resistor, fixed, 12 k, 1/4 w		RC07GF123J
R333	Resistor, fixed, 680, 1/4 w		RC07GF682J
R336, 39, 51	Resistor, fixed, 100, 1/4 w		RC07GF101J
R337, 8	Resistor, variable, 100 ohm, 1/2 w	Bourns	3300P

1 kHz AMPLIFIER (P/N 212150) (cont)

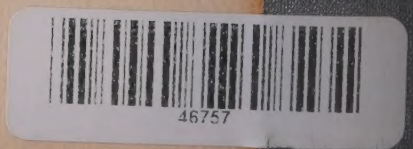
Reference Symbol	Description	Manufacturer	Part Number
R341, 42, 45, 46, 47, 48, 49, 50	Resistor, fixed, 1.1 k, 1/4 w		RC07GF112J
R343, 344	Resistor, fixed, 51 ohm, 1/4 w		RC07GF510J
R352	Resistor, fixed, 3.3 k, 1/4 w		RC07GF332J
R353	Resistor, fixed, 200, 1/4 w		RC07GF201J
R355	Resistor, variable, 1 k, 1/2 w		3307P
R357	Resistor, fixed, 470, 1/4 w		RC07GF471J
R358	Resistor, fixed, 39 k, 1/4 w		RC07GF393J
R354, 64, 65	Resistor, fixed, 1.8 k, 1/4 w		RC08GF182J
R360	Resistor, fixed, 40.2 k, 1%	1 RC	DCC
R361	Resistor, fixed, 20 ohms, 1%	1 RC	DCC
R362	Resistor, fixed, 470 k, 1/4 w		RC07GF474J
R367	Resistor, fixed, 1.5 k, 1/4 w		RC07GF152J
	AUTOMATIC FREQUENCY CONTROL (P/N 212375)		
C401-408, 411 12, 13, 16, 17, 18, 20	Capacitor, ceramic, 1000 pf		CK05CW102K
C409, 414	Capacitor, ceramic, 270 pf		CK05CW271K
C410, 415	Capacitor, ceramic, 390 pf		CK05CW391K
C419	Capacitor, ceramic, 56 pf		CK05CW560K
C421, 30, 39	Capacitor, electrolytic, 15 µf, 25v	Sprague	TE1205
C422	Capacitor, variable, 0.8-10 pf	Johanson	JMC2951
C423	Capacitor, glass, 62 pf		990137-24
C424, 25	Capacitor, ceramic, 680 pf		CK05CW681K
C426-429, 431, 33, 40, 41, 42	Capacitor, electrolytic, 15 µf, 20v		CS13BE156M
C432, 37, 38	Capacitor, electrolytic, 1 µf, 35v	Sprague	15017105 x 9035A2
C434, 435	Capacitor, mica, 0.015 µf	Westlap	4M153K
C436	Capacitor, mica, 0.027 µf	Westlap	4M273K
C443	Capacitor	Sprague	4C38
C444, 5	Capacitor, electrolytic, 47 µf, 35v		CS13BF476K
C446, 47, 48	Capacitor, feedthru	Allen-Bradley	FB2B
CR401, 2	Diode	Hewlett-Packard	HPA-3039
CR403-408	Diode		1N100

AUTOMATIC FREQUENCY CONTROL (P/N 212375) (cont)

Reference Symbol	Description	Manufacturer	Part Number
CR409, 10	Diode		1N87A
CR411-414	Diode		1N4009
J4, 10, 15, 16	Connector, BNC		VG 1094/U
L401, 2, 4, 6 8, 10	Inductor, molded, 3 μh	Speers Carbon	10100-2
L403, 405	Inductor, variable	AIL	118244-11
L407	Inductor, variable	AIL	118244-1
L40R	Inductor, variable	AIL	212148
Q401, 402	Transistor		2N2996
Q403	Transistor		2N1141
Q404, 6, 7, 10	Transistor		2N3819
Q405, 8, 9	Transistor		2N4123
R401, 8, 21, 34, 51, 54	Resistor, fixed, 1 k, 1/4 w		RC07GF102J
R402	Resistor, fixed, 3.9 k, 1/4 w		RC07GF392J
R403, 23, 69	Resistor, fixed, 10, 1/4 w		RC07GF100J
R404, 11, 17, 29, 30, 45, 67	Resistor, fixed, 10 k, 1/4 w		RC07GF103J
R405	Resistor, fixed, 12 k, 1/4 w		RC07GF123J
R406	Resistor, fixed, 4.7 k, 1/4 w		RC07GF472J
R407, 453	Resistor, fixed, 68 k, 1/4 w		RC07GF683J
R409, 14, 19	Resistor, fixed, 2.7 k, 1/4 w		RC07GF272J
R410, 15, 20, 58	Resistor, fixed, 51, 1/4 w		RC07GF510J
R412, 16	Resistor, fixed, 6.2 k, 1/4 w		RC07GF622J
R413, 18	Resistor, fixed, 20, 1/4 w		RC07GF200J
R424	Resistor, fixed, 560, 1/4 w		RC07GF561J
R425	Resistor, fixed, 470, 2 w		RC42GF471J
R426, 27	Resistor, fixed, 51 k, 1/4 w		RC07GF513J
R428	Resistor, fixed, 120 k, 1/4 w		RC07GF124J
R431, 48	Resistor, fixed, 200 k, 1/4 w		RC07GF204J
R432, 33	Resistor, fixed, 15 k, 1/4 w		RC07GF153J
R435	Resistor, fixed, 22 k, 1/4 w		RC07GF223J
R436	Resistor, variable, 6 k, 1/2 w		3307P
R437, 44	Resistor, fixed, 1 m, 1/4 w		RC07GF105J
R430, 52	Resistor, fixed, 47 k, 1/4 w		RC07GF473J
R439	Resistor, fixed, 27 k, 1/4 w		RC07GF273J
R440	Resistor, variable, 5 k, 1/2 w	Bourns	3307P
R441	Resistor, fixed, 8.2 k, 1/4 w		RC07GF822J

AUTOMATIC FREQUENCY CONTROL (P/N 212375) (cont)

Reference Symbol	Description	Manufacturer	Part Number
R442	Resistor, fixed, 4.7 k, 1/4 w		RC07GF472J
R443, 450	Resistor, fixed, 11 k, 1/4 w		RC07GF113J
R446	Resistor, fixed, 36 k, 1/4 w		RC07GF363J
R447, 49, 63	Resistor, fixed, 20 k, 1/4 w		RC07GF203J
R445	Resistor, fixed, 2 k, 1/2 w		RC20GF202J
R456	Resistor, fixed, 100, 1/4 w		RC07GF101J
R457	Resistor, variable, 100, 1/2 w	Bourns	3300P
R459, 60, 61, 62	Resistor, fixed, 1.1 k, 1/4 w		RC07GF112J
R464, 65	Resistor, fixed, 100 k, 1/4 w		RC07GF104J
R466	Resistor, fixed, 2.2 k, 1/4 w		RC07GF222J
R468	Resistor, variable, 10 k, 1/2 w		RV62AYSA103A
T1	Transformer	Triad	TY28X-T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